Synthesis of Polymer Nanocomposites Based on Nano-Alumina: Recent Development

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Abstract:

One of the most promising uses for alumina nanoparticles (Al_2O_3 NPs) is in analytical chemistry, where their excellent physiochemical characteristics make them stand out from other metal oxides. Adequate dispersion and adequate interfacial contact between the reinforcer and the polymer matrix are required to use the Al2O3 NPs as an efficient nano-filler in the polymer nano composites (NCs). Al_2O_3 NPs have organic coupling agents grafted onto their hydrophilic surface for this purpose. Polymer/Al_2O_3 nanocrystals (NCs) have been the subject of much study over the last several decades, with researchers primarily interested in exploring the material's structure-property correlations as it evolves. This review provides a narrative explanation of the principles, methods, and effects of dispersing and modifying Al_2O_3 NP in polymer/Al_2O_3 NC.

Keywords: Polymer, Alumina NPs, Polymer matrix, Metal Oxides, Alumina nanoparticles, Polymer nanocomposites.

1. Introduction

The goal of making polymer/inorganic nanocomposites (NCs) is to create polymeric materials with enhanced/desired characteristics by grafting the synthetic polymer on inorganic particles or by integrating modified metal oxides in the polymer phase [1,2]. Any composite includes the bulk matrix, the filler, and the matrix between the two, known as the interfacial region. The interfacial area of a polymer has unique characteristics compared to the bulk matrix [3,4] because of its proximity to the filler surface. The characteristics of polymer NCs doped with alumina nanoparticles (Al_2O_3 NPs) have been shown to vastly improve, even at negligible nano-fillers loadings. When metal oxides and polymeric phases are combined, the faults of one may be mitigated without sacrificing the benefits of the other [6,5]. The packaging, fibre, automotive, field separation, catalysis, biomedical, and other industries might all benefit from the unique properties of NC materials. Here, we examine the process of immobilisation, or the attachment of molecules to a surface, and how it is used to coat Al_2O_3 NP. Successes and future directions in polymer/ Al_2O_3 NCs, including the impact of nano-alumina on NC characteristics, will then be given.

2. Alumina NPs and their properties

Aluminium oxide, or alumina (Al_2O_3), occurs in nature as the pure mineral corundum (Al_2O_3), the hydrated mineral diaspore ($Al_2O_3.H_2O$), the hydrated mineral gibbsite ($Al_2O_3.3H_2O$), and the impure form of gibbsite, bauxite [7]. In addition to the thermodynamically stable - Al_2O_3 (corundum), a wide variety of other crystalline forms of alumina exist. It is possible to permanently convert metastable phases, also known as "transition alumina" phases, to - Al_2O_3 with the use of suitable heating or hydroxylation treatments [8, 9]. The heat treatment paths of Al_2O_3 transformation are shown in Figure 1. Alumina has both hexagonal and octahedral sites in its crystal structure [10,11].

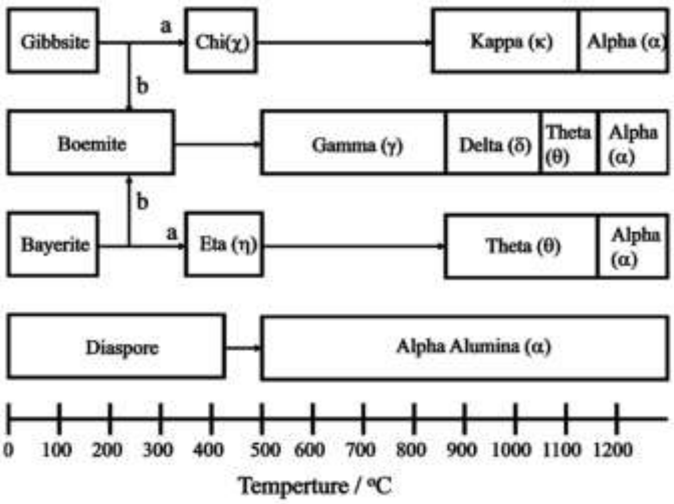

Fig. 1. Structure transformation of alumina and aluminum hydroxides.

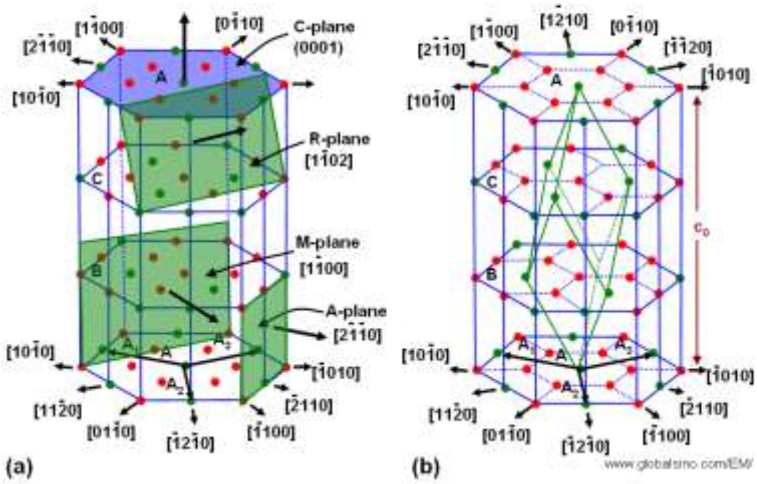

Fig. 2.Structure of α- Al_2O_3.

The average crystallite size of Al_2O_3 powder is reported to get larger with higher calcination temperatures by a number of sources. Particles tend to clump together more strongly when their growth rate accelerates beyond their nucleation rate. In order to produce particles with a narrow size distribution (Fig. 3) [12-14], a low calcinations temperature is necessary.

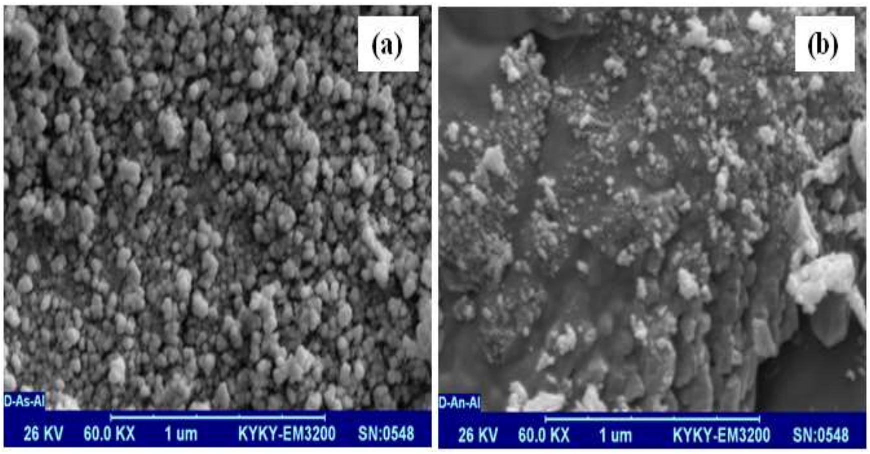

Fig. 3. SEM alpha Al_2O_3.

Al_2O_3 NP has been synthesised by sol-gel processes [15, 16], flame spray pyrolysis [17], precipitation [18], hydrothermal [19], and combustion [20].The co-ordinately unsaturated site anions and cations on a metal oxide solid crystal's surface are truncated. When exposed to the environment, water covers the surface of a metal oxide. Water absorption may cause surface terminal OH groups [21, 22].Alumina nanoparticles (NPs) offer several desired properties, including high strength and stiffness, mechanical strength, inertness to most acids and alkalis, high adsorption capacity, wear resistance, oxidation resistance, thermal stability, and electrical insulation. It scours well, is inexpensive, and nontoxic [23-25]. Table 1 lists Al_2O_3 NP physical and mechanical properties [7]. The physiochemical properties of Al_2O_3 NPs suggest applications in pigments, porous ceramic membranes, catalysts or catalyst carriers, ultra-filtration membranes, electrical insulators, high voltage insulators, furnace liner tubes, ballistic armour, abrasion-resistant tubes and thermometry sensors [25-26].

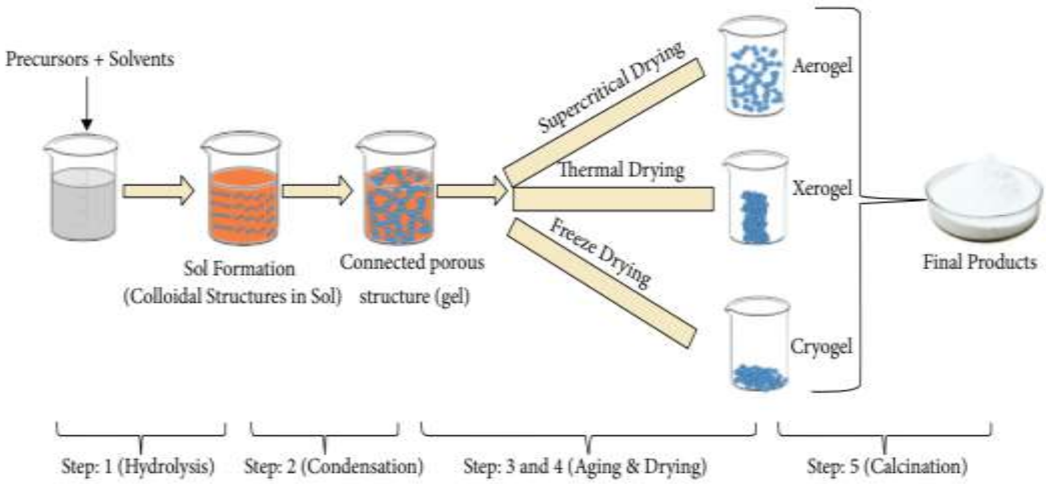

Fig. 4. Al_2O_3 NP synthesized by sol-gel processes.

Table 1: Physical properties of Al_2O_3 NPs.

Properties	**Condition**	**Units**	**Values**
Bulk density	20 °C	g/cm_3	3.96
Tensile strength	20 °C	Mpa	220
Elastic modulus	20 °C	Gpa	375
Hardness	20 °C	Kg/mm_2	14
Thermal conductivity	20 °C	W/m°k	28
Dielectric constant	1 MHz	-	9.7

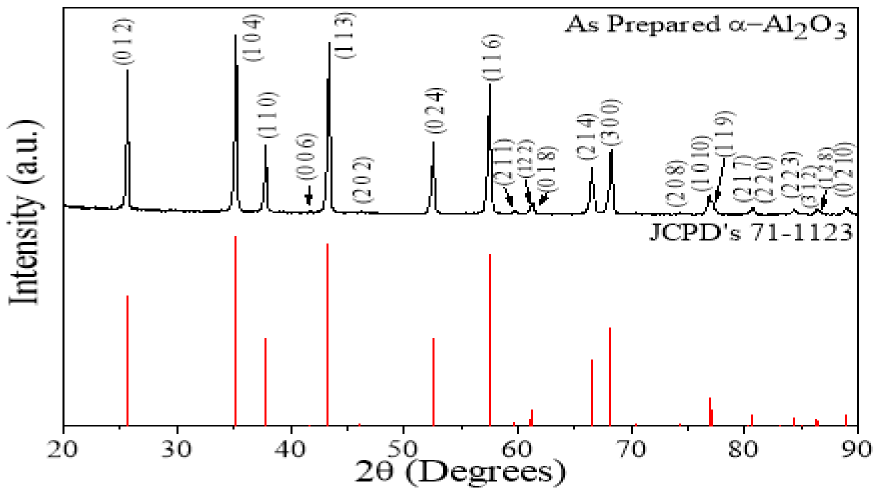

Figure 5. XRD of alpha Al_2O_3 NP.

3. Surface Analysis of Al_2O_3 NPs

Research efforts have been focused on developing polymer/ Al_2O_3 NCs for industrial and architectural uses [11]. Nano-metal oxides have shown great promise as reinforcements, but their full potential has been hampered by issues with inadequate diffusion and poor interfacial contact between fillers and the polymer matrix. Developing an appropriate surface coating to reduce NP aggregation is essential for resolving these problems. Several methods, including chemical functionalization and silane coupling agents, have been proposed for modifying the NPs' surfaces. Figure 5 shows the surface modification of Al_2O_3 NPs by the XRD pattern. Al-O-Si bonds are formed when -OH groups on Al_2O_3 NPs react with silane alkoxy groups. The surface of NPs may also be modified using organosilane precursors. Chemical functionality is improved and surface topology is altered for both native inorganic and organic materials when synthetic polymers are grafted onto the surface of Al_2O_3 NPs [10]. The adsorption ratio of surfactants and the magnitude of steric repulsive force are both affected by the molecular weight of the polymer surfactant and the particle size of the nano-alumina. Polymers may be attached to the surface of inorganic particles by covalent bonding using either the "grafting to" or "grafting from" techniques. In order to modify the surface of Al_2O_3 NPs, the "grafting to" and "grafting from" techniques are the two most often used approaches. By reacting functional groups on the NP surface with reactive end groups of premade polymers, the "grafting to" approach grows polymers on the NP surface, whereas the "grafting from" method grows polymers in situ using surface immobilized initiators. Ionic surfactants, ball-milling in toluene media, and biodegradable dicarboxylic acids including natural amino acids are further techniques of surface treatment [23].

4. Properties of modified Al_2O_3 NP

Many acid catalysts rely on Al_2O_3-based materials for their acidic activity. However, as-received Al_2O_3 NP has a low surface area and loses some of its activity during the reaction because of their hydrophilic nature and tendency to clog [16]. Vanadium species' sites on lithium-, sodium-, and potassium-modified aluminas were studied by Santos et al., who concluded that potassium-modified alumina with a larger surface area performed better in the $DeSO_x$ process. Hydrothermal synthesis of mesoporous Al_2O_3 NP from aluminium sulphate is possible. In order to synthesise new 1,4-dihydropyridine compounds, functionalized alumina was used as a reusable and heterogeneous catalyst [22]. Effective alternatives include adsorption by inert solid adsorbents.

6.Result and Discussion

Nanoparticle composites (NCs) in polymers are made by dispersing inorganic nano-additives across a polymer matrix [8]. Polymer materials' development and equilibrium may benefit from their insights. Solution blending, ultrasonication, and solution casting are the most common methods for physically and chemically entrapping the metal oxides NPs in the polymer networks [1-4]. By using ultrasonication, Prakash et al. encased Al_2O_3 NPs, which are biocompatible, in a chitosan biopolymer matrix. Ocando et al. investigated how adding modified alumina NPs to a dispersion of poly(styrene-butadiene-b-styrene) linear triblock copolymer affected the self-assembled morphology of the polymer. Incorporating lithium triflate salt, ethylene carbonate as a plasticizer, and Al_2O_3 into a poly(ethylene oxide) host matrix, Johan et al. developed a polymer electrolyte NC [7, 17-19].

6. Conclusions

Access to alumina NPs and increased understanding of how to disperse and integrate the particles into the polymer matrix have provided fresh perspectives on how to design effective NCs. A wide variety of Al_2O_3 NPs-based manufacturing techniques for high-performance polymer NCs have been investigated. Depending on their composition and how they react with polymers, they may either improve or reduce stability. Several NCs with great untapped potential can be formed by incorporating nano-alumina into an organic matrix. In this article, we summarise the studies conducted on Al_2O_3/polymer N.

Conflicts of Interest: The authors have not any potential conflicts of interest. To collect and analyses data, to write amanuscript, and to decide whether or not to publish findings.

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