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RESEARCH

Synthesis and structural and mechanical properties of nanobioceramic (α-Al_2O_3)

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Abstract
The structural and mechanical properties of the nanostructured alpha-alumina (α-Al_2O_3) compact powders, formed by calcination of aluminum hydroxide ($Al_2(OH)_6$) gibbsite at different temperatures (100–1100 °C), followed by uniaxial pressing and subsequently hot isostatically pressed (HIP), were investigated using X-ray diffraction, scanning electron microscopy (SEM), and type ball-on-disk oscillating tribometer. X-ray diffraction analysis indicates that the transformation sequence involves the formation of κ-Al_2O_3 as an intermediate phase between χ- and α-Al_2O_3. The crystallite size of calcined alumina (α-Al_2O_3) was as small as 8 nm after calcination at 1100 °C. The sliding friction and wear rate were lower in the nanocrystalline samples calcined at 1100 °C at same applied load (3, 6, or 10 N). The enhanced friction and wear resistance were endorsed to have fin microstructure similar to the sample calcined at 1100 °C.

Keywords Nanotribology · Calcination · Sintering · Friction and wear tests · α-Al_2O_3

Introduction

Tribological problems in the prosthesis for substitution of hip joints were widely studied [1–6]. The choice of the materials for the total hip prosthesis takes many properties such as mechanical resistance and tribological behaviors [7–10] into consideration. The widespread use of advanced bioceramics α-Al_2O_3 depends on the ability to control the microstructural development during processing and to obtain submicron grain size with full density [11]. A polymorphic transformation of alumina through the different metastable forms like γ, δ, and θ to the α phase which is the most thermodynamically stable compound of oxygen and aluminum occurs irreversibly under heat treatment [12–14].

Alumina (Al_2O_3) nanopowders can be used for the fabrication of ceramics with improved hardness, wear resistance, and biocompatibility [15–19]. A reduction in the size of the alumina particle from micron level to nanoscale, properties such as surface area and chemical reactivity are enhanced. Due to this, nanosized alumina powders are employed in making fine coatings; high-temperature alumina ceramics, soft abrasives, and adsorbents have increased considerably [20–22].

Several methodologies were used to synthesize nanosized alumina powder [23–25]. Upon heating of the alumina nanopowder followed by dehydration of water structure, dehydroxylation and structural changes of the intermediate metastable phases, nucleation, and growth [26, 27] of the ultimate stable phase α-Al_2O_3 (corundum) occur.

Nanosized α-Al_2O_3 particles have great importance because of their unique physical, chemical, and mechanical properties. But, the preparation of nanosize α-Al_2O_3 powder is difficult and still remains a challenging issue, the reason being the requirement of a very high calcination temperature for this stable phase formation. At this high temperature, the possibility of grain growth is higher which restricts nanosized feature in the end product of the synthesized particle. Another factor is that, the tendency of agglomeration of α-Al_2O_3 powder is high during dehydration [28].

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