ALUMINUM OXIDE-BASED CERAMIC COMPOSITE MATERIALS

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Among mineral-ceramic materials, alumina-based ceramics are widely used across various industrial sectors due to the abundance of their raw materials in nature, as well as their high hardness, chemical inertness, and superior wear resistance. Furthermore, ceramic cutting tools made from these materials offer distinct advantages—such as superior hardness, wear and corrosion resistance, and low chemical reactivity with the metals being machined—allowing for higher machining speeds compared to traditional high-speed steels or cemented carbide tools. White ceramic-based tools enable the machining of various difficult-to-cut materials, including hardened steels and numerous non-ferrous metal alloys. This underscores the immense importance of ceramic materials in the field of tool manufacturing.

Aluminum oxide is obtained from naturally occurring aluminum-bearing minerals. There are stable (α, β, γ—hexagonal and cubic lattices) and unstable (δ—hexagonal and θ—monoclinic) modifications of aluminum oxide. β-Al_2O_3 is not considered a pure modification of aluminum oxide; its presence within corundum (α-Al_2O_3) reduces the material's strength.

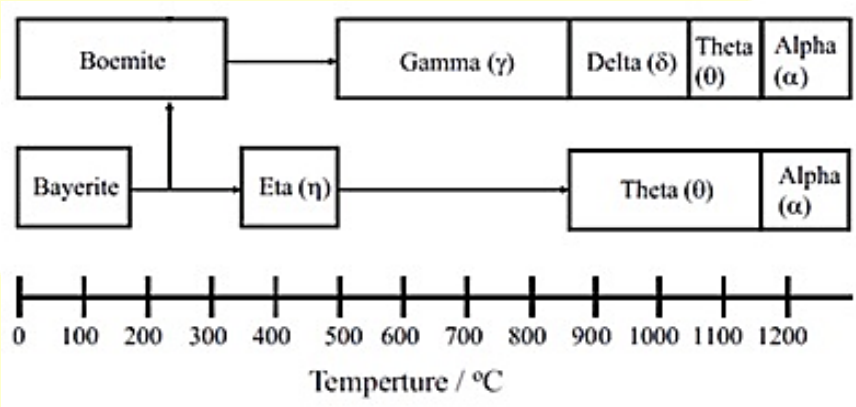


Figure 1. Phase transformation in aluminum oxide

Aluminum oxide primarily occurs in bauxite ores in the form of hydroxide, with concentrations ranging from 50% to 100%. Depending on the ore quality, it is

processed using either dry-alkaline or wet-alkaline methods. The process involves first obtaining sodium aluminate, followed by aluminum hydroxide, and finally aluminum oxide. When producing high-density ceramic components, the Na_2O content must be kept below 0.1%. α-Al_2O_3 remains stable when heated up to its melting point, undergoing no phase transformations. Heating aluminum hydroxide yields γ-Al_2O_3, which converts to α-Al_2O_3 when heated above 1200°C. This process proceeds slowly, completes fully between 1400°C and 1450°C, and is accompanied by the release of heat. Technical-grade alumina consists primarily of γ-Al_2O_3, along with other impurities. Since it is difficult to manufacture high-quality components directly from technical-grade alumina, the material is heated to temperatures between 1500°C and 1750°C, causing the γ-Al_2O_3 within it to transform into α-Al_2O_3. Research results indicate that to improve the aluminum oxide firing process, the powder must be free of aggregates and consist of finely dispersed particles; the recommended particle size is 10 μm. Furthermore, research indicates that a spherical powder shape prevents anisotropic volumetric shrinkage, while a powder particle size of 1 μm increases the densification level of the sintered parts.

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