ADVANCED CERAMIC COMPOSITE MATERIALS PRODUCTION TECHNOLOGIES

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Sintering is the process of heating powders to a temperature below their melting point, causing them to bond together. During this process, diffusive mass transfer occurs between the powder particles, bonds are formed, and a dense solid body is produced [1]. Scientists have proposed various sintering technologies—which have been continuously refined over the years—to produce ceramic materials with highly densified microstructures and superior mechanical properties at elevated temperatures [2]. Technologies such as conventional sintering, hot pressing, hot isostatic pressing, plasma sintering, and microwave sintering are widely used for sintering ceramic powder materials.

Pressureless sintering is a relatively simple and cost-effective technology carried out in two stages: first, sufficiently strong briquettes are produced via single-action cold pressing, and second, they are sintered at a specified temperature. Indian scientist Seema Patil [3] investigated the effect of cooling rate on mechanical properties during pressureless sintering and observed that, as the cooling rate decreased, flexural strength (1172 MPa at 5 °C/min) and fracture toughness (9.52 MPa·m$^{1/2}$ at 1°C/min) increased. The main drawback of this method is the impossibility of achieving a high degree of densification and a fine-grained microstructure [4].

Hot pressing. In hot pressing, samples are heated using an external heat source and pressed in a hydraulic press. This method is widely used to produce dense Al_2O_3. Sintering aluminum oxide is relatively easy because the high mobility of Al^{3+} and O^{2-} ions at elevated temperatures enhances the rate of diffusion [5]. F. Sommer [6] conducted research on the effect of hot pressing duration on the mechanical properties of ceramic materials. The highest mechanical properties (99.5%, 8.5 MPa·m$^{1/2}$, and 1198 MPa) were determined for the 1%YZTA17% composition under hot-pressing parameters of 1475°C, 50 MPa, and 3 hours. It has been shown that the increased

densification (99.3%) and improved mechanical properties by employing a repeated hot-pressing method (1600, 1650, and 1700°C at 30 MPa for 2 minutes; 1760°C at 35 MPa for 15 minutes). However, the high heating temperatures associated with this method lead to grain growth, which in turn degrades the mechanical properties.

Hot isostatic pressing. Hot isostatic pressing technology differs from other methods in that it enables the production of complex-shaped components with high density. In hot isostatic pressing, the ceramic powder charge is loaded into a deformable shell (a glass ampoule is used for this purpose), and a vacuum is created before the opening is sealed. It is then placed into a furnace where it is subjected to high pressure and temperature. In this process, high pressure is applied to the surface of the workpiece by means of compressed gases (nitrogen or argon). The applied pressure acts perpendicularly on every point of the outer surface of the gas-impermeable plastic shell, ensuring its isostatic compaction (pressing).

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