**Advanced Ceramics: Microstructural Control and Performance Enhancement**

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Ceramics are indispensable materials in modern materials science due to their excellent properties, such as heat resistance, high strength, and corrosion resistance. They are used in a wide range of fields, including aerospace, energy, and electronic devices. Precise control of microstructural factors, such as grain size, grain boundary characteristics, and second-phase distribution, is crucial for significantly improving performance.

A key aspect of microstructural control is simultaneously suppressing grain growth and densification during sintering. Using nanoparticles yields a more uniform, fine-grained structure, enhancing fracture toughness and bending strength. Additionally, efforts to control grain boundary energy with specific additives improve high-temperature creep resistance. These approaches significantly boost material reliability and durability for use in severe environments.

The overall properties of multi-component ceramics are largely affected by the precipitation behavior and distribution of their different phases. For instance, the dispersion of whiskers and particles in composite ceramics is expected to suppress crack propagation and improve material toughness. Advances in computational materials science, through first-principles calculations and molecular dynamics simulations, can elucidate atomic-level phenomena difficult to observe experimentally, offering guidelines for optimal composition and microstructure design (Figure 1).



Fig. 1. Color figures are allowed.

We will introduce recent advancements in microstructure control technologies, detailing their applications and characterization results in specific ceramic systems (e.g., silicon nitride, silicon carbide, zirconia). The presentation will then explore microstructure design's potential to further enhance performance and enable new functions, envisioning the development of next-generation innovative ceramic materials.

[1] C. S. Center, C. S. R. Network, and G. P. Spin, *Mater. Sci. Lett.* **100**, 100100 (2021).