Strategies to enhance properties of 3D-printed ceramics

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ABSTRACT

Technologies of additive manufacturing (AM) impress with the ability of fabricating ceramic parts of high precision and complexity. However, their mechanical performance may be affected by printing process-related parameters as compared to conventionally processed ceramics. To improve strength and damage tolerance of 3D-printed alumina-based ceramics, two different approaches have been investigated, focusing on microstructural and architectural design.

(i) High strength alumina based on a multilayer design: A-B-A laminates of (A) alumina and (B) alumina-zirconia materials were additive manufactured using the 2K-lithography-based ceramic manufacturing (LCM) technology. Through mismatching thermal expansions of the different materials, compressive residual stresses were induced into the surface alumina layers during cooling after sintering. A biaxial strength of 1 GPa was obtained, in comparison to 650 MPa on 3D-printed bulk alumina.[1]

(ii) Damage tolerance alumina: Textured alumina ceramics were 3D-printed by applying the method of templated grain growth. Through shear forces, occurring during the printing process, aligned high aspect ratio templates grew due to the dissolution and precipitation of surrounding submicron-sized powder particles. As a result, anisotropic crystallographic properties as well as the morphology of the textured grains led to a biaxial strength of 670 MPa, compared to 570 MPa measured on equiaxed alumina sintered under the same conditions. Additionally, toughening mechanisms as crack deflection, bifurcation and even crack arrest could be observed, leading to an enhanced damage tolerance.[2]

These two strategies may be applied to other 3D-printed ceramic materials and systems of more complex geometry to enhance their structural properties.

[1] J. Schlacher, A.-K. Hofer, S. Geier, I. Kraleva, R. Papšik, M. Schwentenwein and R. Bermejo, Open Ceramics **5** (2021) 10082.

[2] A.-K. Hofer, I. Kraleva and R. Bermejo, Open Ceramics **5** (2021) 100085