

Double-Tough Ceramics: Leveraging Multiscale Toughening via Material Design, FAST/SPS and Bayesian Optimization

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The traditional labeling of ceramics as brittle materials has been challenged with a variety of strategies. Multiscale designs and controlled phase transformations have shown promising results. Both the processing and mechanical characterization of toughened ceramics, however, require innovative approaches.

We show here how multiple toughening strategies can be combined into bulk all-ceramic materials consisting of alumina and zirconia. We present an optimization-driven approach to create a double-tough ceramic with a brick-and-mortar microstructure, where the zirconia mortar surrounding the alumina bricks is transformation-toughened, engineered with the goal of simultaneously achieving high strength and fracture toughness. As the design of such a material requires a laborious trial-and-error approach, we propose Bayesian Optimization (BO) as an integral part of our methodology.

FAST/SPS is key to achieve our goal. It promotes densification and the development of a textured microstructure, and it enables the retention of nanograined zirconia with a prevalence of tetragonal phase. BO guides the experimental campaign. We use a Gaussian process to emulate the material's mechanical response and implement a cost-aware batch optimization to identify optimal design process parameters, accounting for the cost of experimentally varying them.

The result is an all-ceramic composite with an exceptional balance between bending strength (>700 MPa) and toughness (>13.5 MPa·m^{0.5}).

Professional Status of the Speaker

Senior Scientist

Interest in submitting a paper in a special issue of

No interest

Invitation letter for visa

No

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