



**New Insights into Oxide Grain Boundary Transport  
through Ultrahigh Temperature *in situ* TEM-based  
Single Grain Boundary Creep and Sintering Experiments**

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**Abstract:** Oxide grain boundaries remain somewhat enigmatic microstructural features. Although much is known about the structure, properties, and distributions of these interfaces, large knowledge gaps remain in our understanding of their transport mechanisms and thermodynamics. In most oxides, considerable disagreement remains regarding the fundamental transport mechanisms that give rise to kinetic processes such as diffusion, sintering, creep, or grain growth. These processes govern the high temperature performance of oxidation barriers, structural materials for extreme environments, high temperature fuel cells, etc. Additionally, the nature of the defects that mediate transport in grain boundaries are largely unknown. For example, are they single point defects, clustered defects, line defects, localized or delocalized defects? Related information has been obtained from atomistic calculations in metallic systems, but analogous calculations are still too complex to apply to oxides. We posit that determining these properties will provide new insights into grain boundary transport mechanisms and form the basis for new strategies aimed at controlling them.

This work develops and demonstrates a combination of *in situ* transmission electron microscopy-based microscale single grain boundary Coble creep and zero creep experiments to measure grain boundary thermodynamic and kinetic properties in cubic  $ZrO_2$  between  $\approx 1200$  °C and 2100 °C. The methodology is based on a combination of *in situ* microscale mechanical testing and localized laser heating. The approaches enable accurate determination of grain boundary and surface diffusivities and energies. The activation volume, migration volume, and formation volume for grain boundary cation diffusion is determined from stress dependent measurements. These data provide insights into the nature of the grain boundary diffusion mediating defect. Finally, the discrete nature of the sintering and creep process observed in the microscale experiments supports the hypothesis that sintering and Coble creep are governed by the motion of grain boundary disconnections. The rotation of grains coupled to grain boundary migration also suggests that grain boundary motion in  $ZrO_2$  is, at least in part, controlled by the migration of grain boundary disconnections.

**Biography:** Shen J. Dillon is an Associate Professor in the Department of Materials Science and Engineering at the University of Illinois at Urbana-Champaign. He received his B.S. and Ph.D in Materials Science and Engineering from Lehigh University in 2007. He worked as a Research Associate at Carnegie Mellon University and a Visiting Research Scientist at the Massachusetts Institute of Technology. He joined the faculty at the University of Illinois at Urbana-Champaign in 2009. His scientific interests relate to understanding the key role played by inorganic interfacial structure-property relationships in affecting the performance of systems relevant to energy generation, conversion, and storage. Much of his recent work has related to developing and applying novel *in situ* characterization techniques that can be applied to understanding the dynamic properties of materials and their interfaces. He is the author of over 90 articles, and was a recipient of the 2011 Department of Energy Science Early Career Award, the 2013 National Science Foundation CAREER Award, and the 2015 American Ceramic Society's Robert L. Coble Award for Young Scholars.