College of Engineering

Department of Mechanical & Industrial Engineering

The Robert W. Courter Seminar Series

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Stressing interfaces to change microstructures: effects of electric fields

by Prof. Klaus van Benthem

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Abstract: Atomic-scale defect configurations determine the properties and functionalities of materials. The application of stress fields such as elevated temperature, modified gas phases, or externally applied electric fields can alter surface and interface structures. In this presentation I will review two projects that have used electric fields and gas phases at elevated temperatures to modify grain boundary core structures and grow individual nanostructures, respectively. Using bicrystal experiments we have previously demonstrated that electric fields directed across grain boundary planes can alter the atomic and electronic structures of (100) twist grain boundaries in $SrTiO_3$. Electric fields directed along the interface plane alter the atomic and electronic grain boundary structures as a function of field strength and proximity to the positive and negative electrodes. EELS and XPS have revealed field-induced oxygen ion migration along the interface planes. Electric fields directed along a 24^{o} tilt grain boundary in $SrTiO_3$ also show a field-induced transition of the grain boundary core structures between the two non-contacting electrodes. Results suggest anisotropic vacancy migration. In a parallel study a series of bicrystals were fabricated from either 0.01 wt% Fe-doped single crystals or undoped single crystals onto which a 0.5nm thick layer of iron was sputter deposited prior to diffusion bonding. After successful diffusion bonding one bicrystal that was formed after Fe deposition was thermally annealed for an additional 200hr. After diffusion bonding STEM characterization detected increased Fe signals from the grain boundary cores of both types of bicrystals. Fe enrichment occurred either by segregation from the doped single crystals or by dopant out-diffusion into the bulk away from the deposited layer. Quantitative EDXS identified that the grain boundary prepared after Fe deposition was characterized by much higher dopant enrichment compared to the case after diffusion bonding of two doped single crystals. Additional thermal annealing of the bicrystal formed after iron layer deposition caused a decrease in interface enrichment approaching the excess observed for the diffusion bonded doped single crystals. The experimental results demonstrate that, dependent on the method of doping, extended thermal annealing of bicrystals may be necessary after diffusion bonding to achieve equilibrium grain boundary excess quantities.

Biography: *Professor Klaus van Benthem is Professor for Materials Science at The University of Alabama in Tuscaloosa, AL. He obtained his PhD at the Max-Planck-Institute for Metals Research in Stuttgart, Germany in 2002. He joined ORNL as postdoctoral fellow in 2003 and worked with Dr. Stephen J Pennycook. In 2007 he became R&D Staff Scientist at the Center for Nanophase Materials Science (CNMS). Klaus was appointed Assistant Professor at UC Davis in 2008 where he received tenure in 2013 and was promoted to Professor in 2018. He relocated to Tuscaloosa, AL in February 2025. Klaus carries out a diverse range of research projects to achieve a fundamental mechanistic understanding of materials phenomena. He uses a variety of electron microscopy and related tools to characterize atomic scale defect structures and their evolution under externally applied stress fields. More recently he has also initiated new efforts in ceramic processing that include diffusion bonding and field-assisted sintering/annealing. His research projects include electric field-induced modifications of grain boundaries and grain growth behavior, wetting-dewetting transitions at metal/ceramic interfaces, and the design of electrolytic etch-stop mechanisms at semiconductor interfaces. Prof. van Benthem has led the advanced electron microscopy and the cleanroom facility at UC Davis. Between 2015 and 2021 he has served as Faculty Director at the UC Davis Office of Research to successfully build and lead the campus-wide Research Core Facilities Program. Owing to this expertise he was recently appointed as Associate Director of the Alabama Materials Institute. Klaus has received numerous awards, including the Young Scientist Award of the German Electron Microscopy Society, a Feodor-Lynen Scholarship of the Alexander von Humboldt Foundation, and the Richard M Fulrath Award of the American Ceramic Society. He became a Fellow of the American Ceramic Society in 2024.*