Fabrication and Structural Design of Ultra-thin MEMS Solid Oxide Fuel Cells

N. Yamamoto, D. Quinn, P. Capozzoli, N. Wicks, S. Wicks, S.M. Spearing, B.L. Wardle (in coll. with B.A. Wilhite, J. Hertz, J. Cui, K. Deshpande, K.F. Jensen, H. Tuller, M.A. Schmidt)
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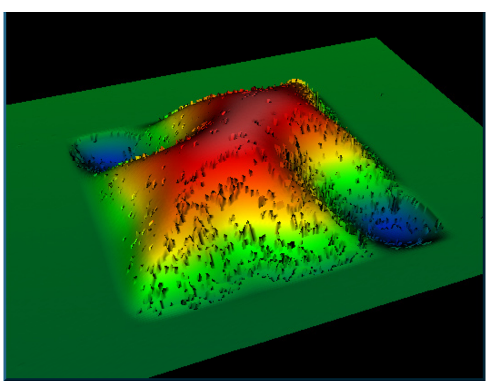
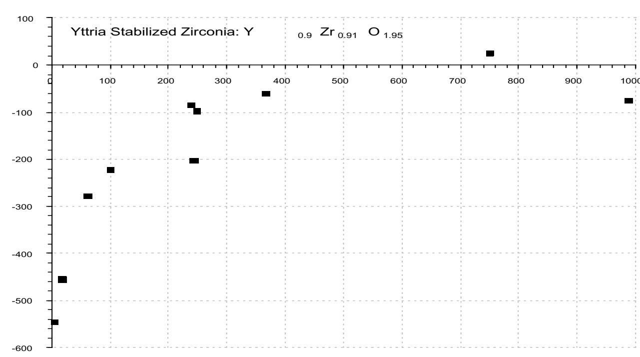
Microfabricated solid oxide fuel cells are being investigated for portable power applications requiring high energy densities [1-2]. Reducing the thickness of the fuel cell stack (anode, electrolyte, and cathode) improves the electrochemical performance over that of traditional devices. This motivation for thinner structures, combined with significant temperature excursions during processing and operation (~600-1000 °C), leads to a major challenge of thermomechanical stability of such membranes. Figure 1 shows a buckled electrolyte/SiN thin film. To predict and control structural stability and failure, the structural characterization of thin films is being investigated.

Our group has characterized the residual stress and microstructure of the electrolyte layer. Complete studies were done on residual stress in sputter-deposited yttria-stabilized zirconia (YSZ) thin films (5 nm-1000 nm thickness) as a function of substrate temperature [3]. The results indicate variations in intrinsic stress from ~-0.5GPa to ~50 MPa as in Figure 2. Changes in microstructure are characterized using x-ray diffraction of as-deposited and annealed films and correlated with relevant mechanisms/models of residual stress evolution. Based on the design frameworks using the data above, a large-area full fuel cell stack (anode, electrolyte, and cathode) has been fabricated and tested to be thermomechanically stable at high operating temperatures. Tri-layers (Pt-YSZ/YSZ/Pt-YSZ, 50-200-μm wide, each 250-nm-thick) were sputter-deposited at high temperature (500-600C). Devices are being tested for electrochemical performance and power generation. In addition, proton-conducting electrolytes, typically capable of significant power generation at temperatures lower than YSZ are also being investigated in ultra-thin film form. Crack-free barium cerium-yttrium-oxide (BaCeYO) films with uniform thickness (300-500-nm thick) have been successfully sputter-deposited. Electrochemical and residual stress characterization for this material is currently underway.

Additional ongoing work includes bulge-testing to determine the electrolyte's elastic/thermal/fracture properties in ultra-thin membrane form, investigation of the mechanical and chemical properties of anode cathode materials, and nonlinear modeling of film postbuckling and failure.



▲ Figure 1: Postbuckled YSZ/SiN membranes on Si. Displacement contour plot.



▲ Figure 2: The YSZ electrolyte film stress as a function of film thickness.

REFERENCES

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