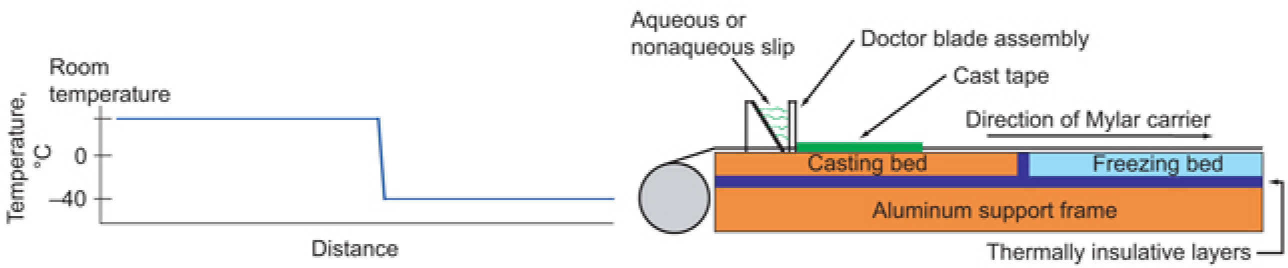
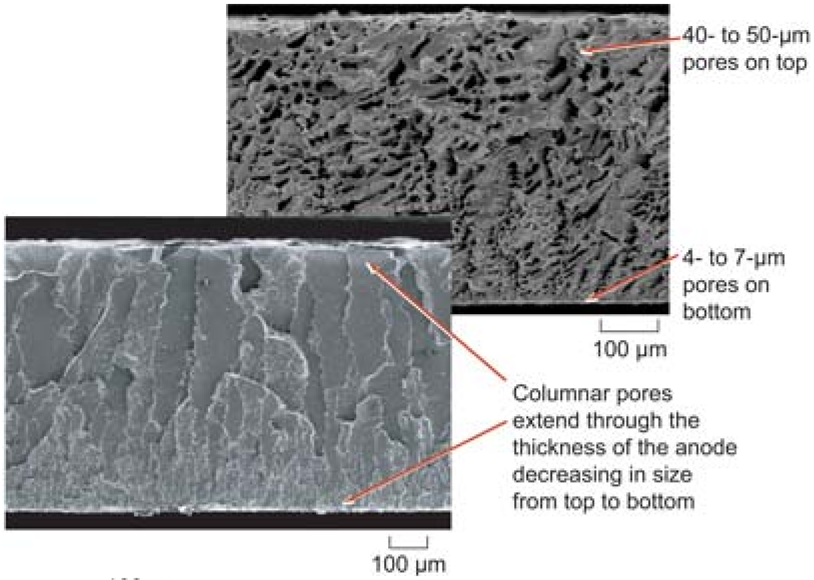
Process Developed for Fabricating Engineered Pore Structures for High-Fuel-Utilization Solid Oxide Fuel Cells

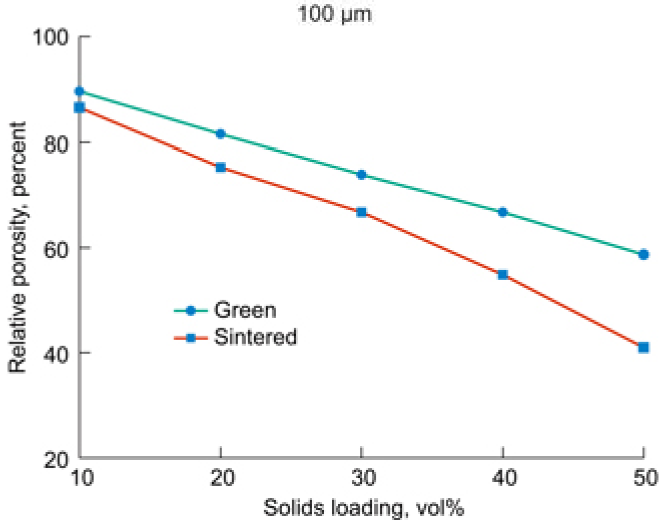
Solid oxide fuel cells (SOFCs) have tremendous commercial potential because of their high efficiency, high energy density, and flexible fuel capability (ability to use fossil fuels). The drive for high-power-utilizing, ultrathin electrolytes (<10 µm), has placed an increased demand on the anode to provide structural support, yet allow sufficient fuel entry for sustained power generation. Concentration polarization, a condition where the fuel demand exceeds the supply, is evident in all commercial-based anode-supported cells, and it presents a significant roadblock to SOFC commercialization.



Left: Temperature profile at 40 °C processing. Right: Freeze-casting apparatus.
Long description of figure 1. Left: Graph of temperature versus distance. Right: Illustration showing aqueous or nonaqueous slip, doctor blade assembly, cast tape, casting bed, direction of Mylar carrier, freezing bed, aluminum support frame, and thermally insulative layers.

Recently, a novel tape casting process (see the preceding figure) was developed at the NASA Glenn Research Center that allows for the fabrication, in a single processing step, of graded columnar pore structures in a wide variety of materials, including all common SOFC anodes, cathodes, and cermets. This new process, called freeze-tape casting, is based on existing tape casting platforms and can yield continuous large-area membranes. The process uses environmentally friendly water-based slurries to directionally solidify the solvent, thus creating a unique pore structure. The freezing pattern of the ice is realized microstructurally in the form of graded porosity and columnar porosity, depending on the processing parameters. As seen in the micrographs, an order of magnitude difference in pore diameters can be created that span the entire thickness of the samples. Freeze-tape casting further allows for the tailoring of pore structures by controlling slurry solids loading and/or the freezing rate, allowing for easy modification of the final porosity and morphology. The effects of solids loading are shown in the final graph.





Left: Microstructures showing the various morphologies and magnitudes of scale for the porous engineered membranes. Right: Influence of slurry solids loading on the as-processed (green) density and the heat-treated (sintered) density.

Long description of figures 2 and 3. Left: Top micrograph shows 40- to 50-µm pores on top and 4- to 7-µm pores on bottom. Bottom micrograph shows columnar pores extending through the thickness of the anode, decreasing in size from top to bottom. Right: Graph of relative porosity in percent versus solids loading in volume percent for green and sintered samples.

Although this technology has potential for a growing number of applications--including catalyst supports, osmotic membranes, and particulate/liquid filtration--it was developed for enhanced SOFCs. As can be seen in the micrographs of the anode-electrolyte coupling, SOFCs based on this casting technology have the potential for increased fuel utilization (improved gas delivery), increased power density, and decreased weight. Extensive efforts in establishing processing-properties relationships in conjunction with cell fabrication will culminate in electrochemical and mechanical properties testing.

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