NEXTECH MATERIALS

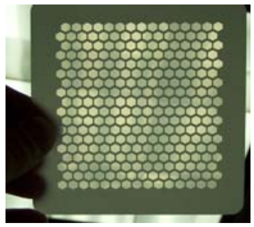
404 Enterprise Drive Lewis Center, Ohio 43035 (614) 842 6606 www.nextechmaterials.com

NexTech's FlexCell Planar SOFC Technology

M.J. Day, S.L. Swartz, M.M. Seabaugh, K. Chenault, and J.R. Archer

NexTech's FlexCell ™ Membrane Architecture

The *FlexCell* is a patent-pending electrolyte-supported planar SOFC cell design comprising a thin electrolyte membrane layer that is mechanically supported by a "honeycomb" mesh layer of electrolyte material. With the *FlexCell*, more than 70 percent of the electrolyte membrane within the active cell area is thin (less than 40 microns). After the bi-layer element is sintered, anode and cathode layers are separately deposited onto the major faces to define the active cell regions. The *FlexCell* combines the attributes of anode-supported and electrolyte supported cell designs, with a thin electrolyte layer for high performance, and the dense periphery for ease of sealing.

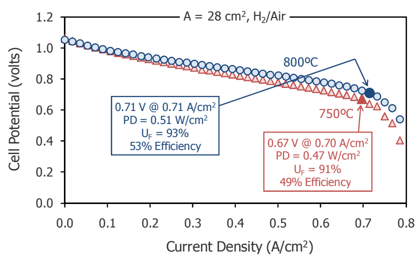


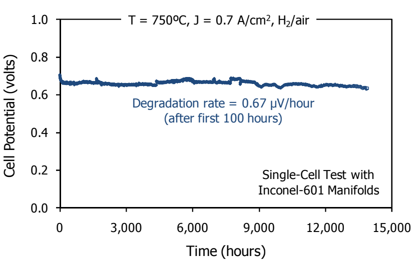
FlexCell Manufacturing

The *FlexCell* membrane is manufactured using inexpensive and scalable manufacturing processes of tape casting, lamination and sintering. A key advantage of the *FlexCell* is that the sintering step is not complicated by differential thermal expansion and sintering shrinkages of component layers. Thus, *FlexCell* membranes can be manufactured at high yields and without curvature or residual stress. Anode and cathode coatings are applied to the *FlexCell* membrane using spray deposition methods that also are scalable to high volume manufacturing.

High Performance & Efficiency

An important advantage of the *FlexCell* is that thin anode layers (less than 50 microns) are not prone to gas diffusion limitations (fuel in and reactants out). This allows *FlexCells* to achieve high power density and high efficiency simultaneously (as shown in the figure to the right). This capability provides system designers with the option of eliminating the anode recycling step, which simplifies the system.



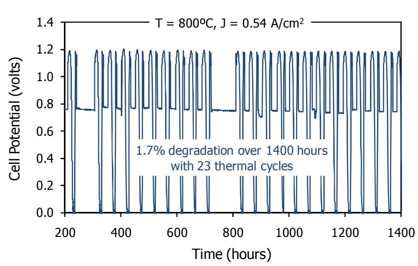


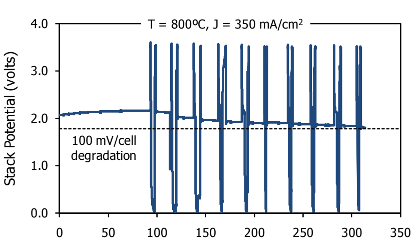
Long-Term Stability

Electrode materials flexibility is an important attribute of the *FlexCell*, since electrodes are deposited in separate steps. Thus, new and improved anode and cathode materials can be incorporated without re-design of the manufacturing process. NexTech's *FlexCell* features a chromium-resistant cathode that has enabled the demonstration of extremely low degradation rates in single-cell tests performed with Inconel-601 manifolds (see figure to the left).

Thermal Cycling

Electrolyte-supported cells are unaffected by stresses associated with thermal expansion mismatches with their thin electrode layers. Thus, the key to achieving thermal cycling tolerance in *FlexCells* is maintaining proper electrode adhesion and stabilizing electrodes from morphological changes that can occur during thermal cycling. As shown in the figure to the right, less than two percent performance degradation was demonstrated over 1400 hours and 23 thermal cycles.



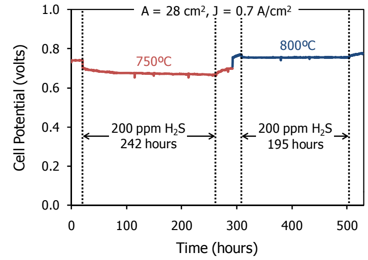


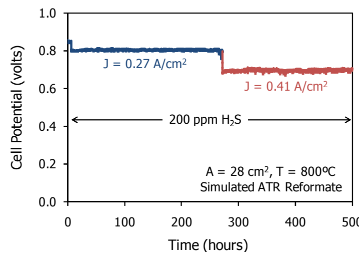
Redox Cycling Tolerance

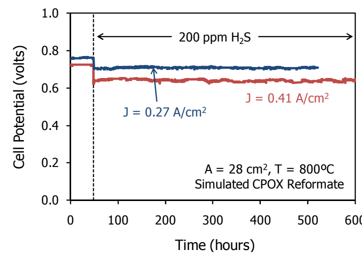
The *FlexCell* architecture features a thin and non-load-bearing anode, which makes the *FlexCell* resistant to damage during cycling between reducing and oxidizing atmosphere. This is illustrated by the figure to the left, whereby a three-cell stack was operated at 800°C and cycled between hydrogen and air within the anode channels. Ten such cycles were completed with less than 100 mV/cell voltage degradation and no degradation of open circuit potential.

Sulfur Tolerant Anodes

NexTech has demonstrated SOFC anodes that are resistant to degradation by sulfur at temperatures above about 750ºC. This capability has significant implications for design of solid oxide fuel cell power systems operating with common hydrocarbon fuels, such as natural gas, propane, LPG, diesel, and coal, all of which contain sulfur in varying amounts. For example, one can design a system with built-in robustness in the event that sulfur removal systems fail. This capability also allows system designers to relax the specifications (and reduce the cost) of desulfurization components.

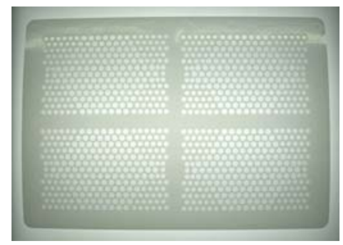


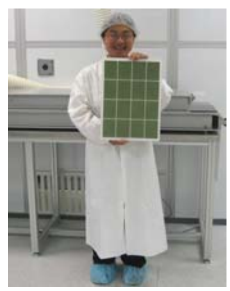


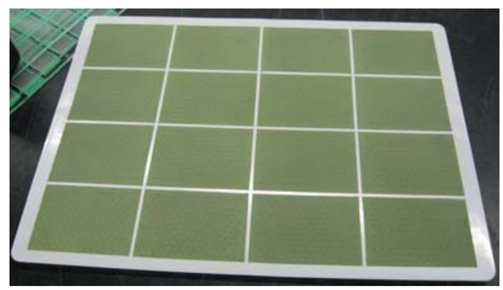


Fabrication of Large-Area FlexCells

One of the key advantages of the *FlexCell* design is that there is no intrinsic limitation to the size of cells that can be made. Scalability is important to the design of stacks when power outputs of 5-kW and larger are being targeted, because these stacks can be produced with a lesser number of cells. This reduces cost associated with stack repeat units and simplifies stacking. NexTech routinely manufactures *FlexCells* with 470-cm² total area targeting 100-150 watts per cell (as shown in the figure to the right), and 1200-cm² area targeting 400 watts per cell (as shown in the figures below).

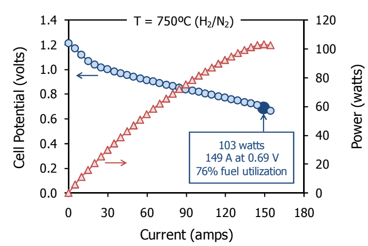


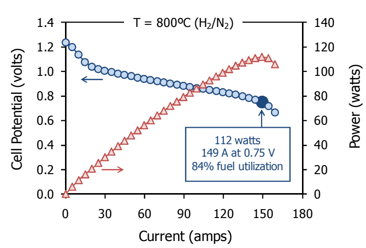


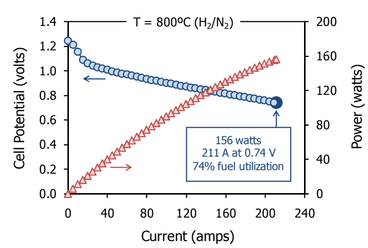


Testing of Large-Area FlexCells

The 470-cm² area *FlexCells* were tested as single-cell stacks with diluted hydrogen as fuel. Data obtained at 750°C (shown in the figure to the right) confirm that a power output in excess of 100 watts was achieved under reasonable operating conditions. Data obtained at 800°C (shown in the figures below) confirmed that power outputs 112 to 156 watts were achieved at high voltage (~0.75 volts) and high fuel utilization (84 and 74 percent, respectively).







Acknowledgements

Funding:

Air Force Research Laboratory
Office of Naval Research
U.S. DOE (SECA)
Ohio's Third Frontier Program
NexTech Materials, Ltd.

NexTech Colleagues

Mike Funk
Kay Tan
Robin Kimbrell
Paul Matter
Lora Thrun