SOFC Materials Technology Development in Support of SECA

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NexTech Materials, Ltd.

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Pittsburgh, PA
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Overview

- NexTech Background
- Multilayer Fuel Cell Program
  - Technical Accomplishments
  - Current Status and Future Plans
- Commercialization Plan
  - Our Mission
  - Where we fit within SECA
  - How we will get there
- Closing Comments
NexTech SOFC History

- Ceria-Based SOFCs
- MLFC
- FuelCellMaterials.com
- Cathode Supported SOFCs
- YSZ Coating Process
- Ceria-Based Electrolytes
- Ceramic Electrolytes

- Started Business Operations

Timeline:
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
SOFC Core Competencies

- Electrolytes – A range of high performance, innovative ceramic powders and coatings
- SOFC Materials: Low-temperature cathode and composite anode materials
- Ceramic Technology: Powder processing, tape casting, screen printing, and co-sintering of ceramic multilayers
Nanoscale Electrolytes

Particle Size (nm)

Nanoscale YSZ Suspension

Nanoscale GDC Powder

Distribution

5 nm
Tailored nanoscale suspension allows for preparation of dense YSZ coatings in a single deposition and sintering cycle.

U.S. Patent Pending
Anode-Supported Cells

Colloidally deposited YSZ Film (NexTech)

Tape Cast Anode Substrate (ORNL)

30 μm
Ceramic Electrolytes

GDC Ceramic (1250°C)

2 μm

Ionic Conductivity (S/cm)

1.000
0.100
0.010
0.001

1000 / T (K⁻¹)

0.80 0.90 1.00 1.10 1.20

900°C  800°C  700°C  600°C

LSGM
SDC
YSZ
Composite Ceria Electrolyte

Mechanical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>SDC</th>
<th>CCE-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (Hv, kg/m²)</td>
<td>780</td>
<td>940</td>
</tr>
<tr>
<td>Strength (MPa)</td>
<td>65</td>
<td>86</td>
</tr>
<tr>
<td>Toughness (K₁₅, MPa-m¹/²)</td>
<td>0.9</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Conductivity vs. Temperature

- SDC-15
- CCE-2
- YSZ
- CCE-10

2 μm
Proprietary Ceria Electrolytes

Ionic Conductivity at 600°C (S/cm)

- NTM A: 0.0176
- NTM B: 0.0166
- NTM SDC: 0.0165
- NTM C: 0.0127
- GDC: 0.0110

NexTech Electrolytes Compared to Literature Reported Data
Nano-Composite Electrodes

Conventional Method

New Method

U.S. Patent Pending
MLFC Fabrication Facility
Low-Cost Manufacturing of Multilayer Ceramic Fuel Cells

DOE Contract No. DE-AC26-00NT40706

Program Manager: Bill Dawson
Principal Investigator: Scott Swartz
Project Manager: Don Collins
Program Plan

Phase I (3 months)
Manufacturing Cost and Risk Assessment

Michael A. Cobb & Co.
Advanced Materials Technologies
Gas Technology Institute

Phase II (12 months)
Development of Fabrication Processes for Planar Cells

NexTech Materials
Oak Ridge National Laboratory
University of Missouri-Rolla

Phase III (9 months)
SOFC Testing, Destructive and Non-Destructive Testing

Northwestern University
Gas Technology Institute
Ohio State University
Cathode Supported Cells

- Tape Casting (Cathode)
- Colloidal Spray (Electrolyte)
- Co-Sintering
- Screen Printing (Anode)

Advanced Materials Technologies  EMTEC  Gas Technology Institute  Iowa State University  Michael A. Cobb & Company  NexTech Materials  Northwestern University  Oak Ridge National Laboratory  Ohio State University  University of Missouri-Rolla
Anode-Supported Cells

- Tape Casting (Anode)
- Screen Printing (Electrolyte)
- Co-Sintering
- Screen Printing (Cathode)

Electrolyte
Anode Interlayer
Anode
Spin-Coated Electrolytes

Tape Casting (Cathode)

Sintering

Spin Coating (Electrolyte)

Screen Printing (Anode)

Advanced Materials Technologies  EMTEC  Gas Technology Institute  Iowa State University  Michael A. Cobb & Company  NexTech Materials  Northwestern University  Oak Ridge National Laboratory  Ohio State University  University of Missouri-Rolla
SOFC Business Plan

- **Our Mission:**
  - Become leading supplier of innovative SOFC materials and manufacturing technology
  - Be materials leader in cost reduction, product reliability, and commercial implementation
  - Be recognized worldwide for technical excellence, integrity, and cooperation
Market Opportunity

Projected Stationary SOFC Market

- Power Sales (MW)
- Year

- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010

0 1000 2000 3000 4000 5000 6000

Technology Development

Customer Acceptance

Market Saturation

Maturity
Scale-Up of YSZ Production

![Diagram showing the relationship between production scale and manufacturing cost. The cost increases significantly with scale.]
How to Get There?

- Supplying materials for qualification to developers in 15 countries
- Beginning scale-up activities
- Currently seeking investors/strategic partners for scale-up/market penetration
- SECA participation
**Electrolyte Products**

- **Nanoscale Powders**
  - YSZ
  - Sc-doped Zirconia
  - Ceria-Based Formulations

- **Nanoscale Suspensions**
  - YSZ
  - Ceria-Based Formulations

- **Conventional Powders**
  - LSGM
  - Bismuth-Based Formulations

- **SOFC elements (coming soon)**

**Electrode Products**

- **Cathode Powders**
  - LSM, LSF, LSCF, etc.
  - LSM/YSZ, LSF/GDC, etc.
  - Custom Formulations

- **Porous LSM Substrates**

- **Anode Powders**
  - NiO/YSZ, NiO/GDC
  - CuO/GDC
  - Custom Formulations

- **Screen printing inks**
Why Work With Us?

- Innovative Products
- Products Engineered for Applications
- Knowledge of Manufacturing
- Path to Cost Reduction
Acknowledgments

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- John Lannutti (Ohio State University)
- Russ Bennett and Gary Kapp (EMTEC)

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