Stable Glass-Ceramic Nanocomposites as Compliant Seals for SOFCs—SEM-COM Company

Background

The challenge in developing a high-temperature seal material for solid oxide fuel cells (SOFCs) results from the dissimilarities between the seal and the components to be joined, in particular, their physical and chemical properties. A criterion that severely limits the use of inorganic, non-metallic sealing materials for SOFCs is their poorly matching coefficients of thermal expansion (CTE) within the operating temperatures (700 to 850 degrees Celsius [°C]) of SOFC stacks.

SEM-COM Company, Inc (SEM-COM) will develop a novel high-CTE hexacelsian glass that will be especially useful in glass-to-metal applications in the SOFC structure. Hexacelsian is a polymorph of celsian, a barium aluminosilicate feldspar. Nanoparticles will be dispersed between the matrix glass and hexacelsian glass particles to prevent the matrix glass from dissolving the filler glass as either a sacrificial coating or a barrier coating. Nanotechnology materials are ideal for this application because their high surface area characteristics will minimize the amount needed to isolate the primary composite glasses.

This fuel cell project was competitively selected under the Small Business Innovative Research (SBIR) Program. It is managed by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL). With the Solid State Energy Conversion Alliance (SECA), NETL is leading the research, development, and demonstration of SOFCs for both domestic coal and natural gas fueled central generation power systems that will enable low cost, high efficiency, near-zero emissions and water usage, and carbon dioxide (CO₂) capture.

Project Description

SEM-COM will develop a composite sealing system with appropriate thermal and mechanical properties to which nanoscale materials have been introduced to inhibit or prevent the dissolution of a hexacelsian phase into the matrix glass, thereby eliminating the CTE drift in the composite system in the 700 to 850°C temperature range. A two-phase mixture or composite will be developed that is stable. One of the phases is a crystalline (devitrified) phase whose composition has been selected to provide a thermal expansion match of the composite to the SOFC system (in the room temperature to glass transition temperature range), and the equilibrium second phase is a vitreous phase to provide the much-needed compliance at the operating temperature.
There are three innovations involved: (1) an inorganic, non-metallic, composite sealing material that at elevated temperatures is compliant so as to provide hermetically sealed materials with dissimilar (non-matching) CTE properties; (2) a glass-ceramic material with a CTE as high as 18 ppm/°C that can be predictably controlled and tailored by varying the heat treatment of the material; and (3) the use of nanoscale materials as barriers in inorganic composite systems to keep various components separate and distinct. The high-CTE hexacelsian glass, especially with the addition of the nanoscale materials, will allow the development of a new family of high-CTE sealing glasses that currently do not exist.

Goals and Objectives
The goal of this project is to develop the materials and processes for a hermetic seal system for SOFCs with the ability to withstand the rigors of normal use over an extended period of time (i.e., 40,000 hours) including dozens of thermal cycles. The objectives are as follows:

- Identify and prepare the appropriate materials.
- Develop the best process to coat and adhere the filler or matrix particles with the nanoparticles.
- Develop a process to mix the system components.
- Measure the properties of the composites (flow, CTE, etc.).
- Develop appropriate thermal cycles.
- Study the microstructure of the glass to confirm dispersion of the nanoparticles.
- Measure CTE stability (e.g., at 8 hours, 96 hours, 300 hours) and crystallization characteristics.
- Evaluate basic compatibility with other SOFC materials including flow and wetting.

Benefits
SBIR’s project assists the SECA program in meeting its cost and performance targets by ensuring that SOFCs can achieve reliable operation over an extended operating life. SECA will ultimately enable fuel cell-based near-zero emission coal and natural gas power plants with greatly reduced water requirements and the capability to capture 97 percent or greater of carbon at costs not exceeding the typical cost of electricity available today. Achieving this goal will significantly impact the nation given the size of the market, the expected growth in energy demand, and the age of the existing power plant fleet. It will also provide the technology base to permit grid-independent distributed generation applications and alternative-fuel vehicles. Federal funding support of this research is appropriate given the game-changing nature of the technology accompanied by risks higher than the private sector initially can accept.