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SOLID OXIDE FUEL CELLS

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INTRODUCTION

Solid oxide fuel cells (SOFCs), based on an oxide ion conducting electrolyte, offer a clean, low-pollution technology to electrochemically generate electricity at high efficiencies. Among all designs of SOFCs, the most progress has been achieved with the tubular design (1). A 100 kW power generation system utilizing tubular SOFCs, fabricated by Siemens Westinghouse Power Corporation, operated very successfully for over two years without any detectable performance change, and a similar 250 kW size system recently started operation. However, the electrical resistance of tubular design cells is high, and specific power output (W/cm^2) and volumetric power density (W/cm^3) low (2). These low power densities make tubular SOFCs suitable only for stationary power generation and are unattractive for mobile applications. Planar SOFCs, in contrast, are capable of achieving very high power densities (3). Additionally, sizeable cost reductions are possible through a concept called “mass customization” that is being pursued in the U.S. Department of Energy’s Solid State Energy Conversion Alliance (SECA) (4). This concept involves the development of a 3 to 10 kW size core SOFC module, that can be mass produced and then combined for different size applications in stationary power generation, transportation, and military market sectors, thus eliminating the need to produce custom-designed and inherently more expensive fuel cell stacks to meet a specific power rating.

PLANAR SOFCs

Currently, electrolyte-supported, cathode-supported, and anode-supported planar SOFCs are under development. In electrolyte-supported cells, the thickness of the electrolyte, typically yttria-stabilized zirconia (YSZ), is 50 to 150 μm, making their ohmic resistance high, and such cells are suitable for operation at ~1000°C. In electrode-supported designs, the electrolyte thickness can be much lower, typically 5 to 20 μm, decreasing their ohmic resistance and making them better suited for operation at lower temperatures (~700-800°C). Lower temperature operation results in less degradation of cell and stack components, makes feasible use of inexpensive metallic interconnects, is less demanding on seals, and aids in faster heat up and cool down. The anode (Ni/YSZ cermet) is selected as the supporting electrode, because it provides superior thermal and electrical conductivity, superior mechanical strength, and minimal chemical interaction with the electrolyte. Kim et al (3) have reported power densities as high as 1.8 W/cm^2 at 800°C for such anode-supported SOFCs. These high power densities make them very attractive for use in the core SOFC module. Cathode and interlayer materials and their microstructures for anode-supported cells are being optimized to achieve higher and stable performance.

Using planar SOFCs, stationary power systems, from 1 to 25 kW in size, have been fabricated and tested by several organizations. Nearly one hundred 1 kW size combined heat and power units using electrolyte-supported cells have been fabricated by Sulzer Hexis, and a few 3 kW size units using anode-supported cells have been fabricated by Global Thermoelectric for residential applications.

PLANAR SOFCs in TRANSPORTATION APUs

Planar SOFCs with very high power densities are ideally suited for transportation applications as well. Delphi Corporation, working with Battelle under the SECA program, has developed a 5 kW automotive auxiliary power unit (APU) using anode-supported planar SOFCs to supply automotive electricity requirements without the need for operating the vehicle engine. This unit is intended to operate on gasoline or diesel, which is reformed through partial oxidation within the APU. Significant improvements have now been made to the initial APU to meet the various design requirements and cost goals; a schematic illustration of their Generation-2 APU is shown in the Figure below.

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