Alumina-reinforced zirconia composites, containing 0 to 30 mol% alumina, were fabricated by hot pressing 10 mol% yttria-stabilized zirconia (10-YSZ) and two different forms of alumina – particulates and platelets. Major mechanical and physical properties, including flexure strength, fracture toughness, slow crack growth, elastic modulus, density, Vickers microhardness, thermal conductivity, and microstructures were determined as a function of alumina content at 25 and 1000°C. Resistance to slow crack growth at 1000°C in air was greater for 30 mol% platelet composite than for 30 mol% particulate composites. Thermal conductivity increased with alumina content.

1. INTRODUCTION

Solid oxide fuel cells (SOFC) are currently being developed for various applications in the automobile, power generation, aeronautic, and other industries. More recently, NASA has explored the possibility of using SOFCs for aero-propulsion under its Zero Carbon Dioxide Emission Technology (ZCET) Project in the Aerospace Propulsion and Power
Program. The SOFC has high-energy conservation efficiency since it converts chemical energy directly into electrical energy. The SOFC is an all solid-state energy conversion device that produces electricity by electrochemical combination of a fuel cell with an oxidant at elevated temperature. The major components of a SOFC are the electrolyte, the anode, the cathode, and the interconnect. The two porous electrodes, anode and cathode, are separated by a fully dense solid electrolyte. Currently, yttria-stabilized zirconia (YSZ) is the most commonly used electrolyte in SOFC because of its high oxygen ion conductivity, stability in both oxidizing and reducing environments, availability, and low cost [1].

In solid oxide fuel cells, YSZ is used in the form of polycrystalline thin films or layers. YSZ must be fabricated in the form of fully dense layers for use as a solid electrolyte in SOFC. Similar to other ceramics, YSZ is brittle and susceptible to fracture due to the existence of flaws, which are introduced during fabrication and use of the SOFC. In addition, the properties of YSZ such as low thermal conductivity and relatively high thermal-expansion coefficient make this material thermal-shock sensitive. Fracture in the solid oxide electrolyte will allow the fuel and oxidant to come in contact with each other resulting in reduced cell efficiency or in some cases malfunction of the SOFC. Therefore, from a structural reliability/life point of view, YSZ solid electrolyte requires high fracture toughness, high strength, and enhanced resistance to slow crack growth at operating temperature (around 1000°C).

To improve the strength and fracture toughness of the electrolyte, the 10 mol% yttria-stabilized zirconia (10-YSZ) was reinforced with 5 to 30 mol% of alumina particulates and platelets. Flexure strength and fracture toughness, determined at 25 and 1000°C in air, together with elastic modulus, density, microhardness, thermal conductivity and other properties of these composites are presented in this chapter. Slow crack growth required for component design and life prediction, evaluated in flexure at 1000°C in air using dynamic fatigue testing for 0 mol% (10-YSZ matrix) and 30 mol% of alumina particulate and platelet composites, is also presented.

2. COMPOSITES PROCESSING

The starting materials used were 10-mol% yttria fully stabilized zirconia powder (HSY-10, average particle size 0.41 μm, specific surface area 5.0 m²/g) from Daiichi Kigenso Kagaku Kogyo Co., Japan, alumina powder [2, 3] (high purity BAILALOX CR-30, 99.99% purity, average particle size 0.05 μm, specific area 25 m²/g) from Baikowski International Corporation, Charlotte, NC, and alpha alumina hexagonal platelets (Pyrofine Plat Grade T2) [4–6] from Elf Atochem, France. Appropriate quantities of alumina and zirconia powders were slurry mixed in acetone and mixed for ~24 h using zirconia media. Acetone was then evaporated and the powder dried in an electric oven. The resulting powder was loaded into a graphite die and hot pressed at 1500°C in vacuum under 30 MPa pressure into 152 mm × 152 mm billets using a hot press. Grafoil was used as spacers between the specimen and the punches. Various hot pressing cycles were tried in order to optimize the hot pressing parameters that would result in dense and crack free ceramic samples. YSZ/alumina composites containing 0 to 30 mol% alumina particulates and platelets were fabricated. Various steps involved during processing of the composite billets are illustrated in Figure 1 [3].