Oxygen Permeation Property of Oxide Ceramics at Ultra-High Temperature

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Carbon/carbon composites are promising materials for ultra-high temperature applications, such as advanced propulsion systems and power generation equipments, because of their excellent mechanical properties at high temperatures. In oxidative environment, carbon materials are significantly oxidized above approximately 800 K. The development of higher-performance oxidation protective coating is required, but none of the coating systems capable of using at the temperature level of 1800 K have been reported. Especially, in compounds containing multiple cations or anions, differences in the transport rates of like-charged ions can lead to morphological changes due to compositional separation in oxygen potential gradients.

Therefore, both the oxygen permeability and morphological stability of the oxides should be evaluated in oxygen potential gradients at ultra-high temperatures to evaluate the capability of candidate oxide ceramics for use as a higher-performance environmental barrier coating (EBCs). In this study, the oxygen permeability of alumina ceramics, which are typical oxides, were measured in oxygen potential gradients and the validity of this measurement technique was evaluated.

Two kinds of alumina materials, single crystal and polycrystalline (purity > 99.99%), were cut to disk specimens of dimensions ∅ 23.5 × 0.25 mm, which were finished the mirror-like surfaces by polishing using diamond slurry to facilitate a gas-tight seal. Platinum gaskets were effectively used to seal the each specimen between the ends of weight-loaded alumina tubes in a furnace.

High purity He and atmospheric O_2 gases were supplied into either side, followed by measuring oxygen permeated from higher P_{O2} side to lower P_{O2} side using an oxygen sensor. Oxygen permeability constants were determined at the temperatures from 1873 to 1973 K.

The oxygen permeability constant of the polycrystalline alumina at 1973 K was determined as 2×10^{-11}kg/(m･s) in good agreement with the previous values, while that of the single crystal alumina was under the detection limit (10^{-12}kg/(m･s)). The oxygen permeation of the polycrystal is attributed to the grain boundary diffusion of the oxygen.

The surface morphology of the polycrystal after the test significantly depended on the oxygen potential gradients during the test. The grain boundary grooves were formed deeply on the surface exposed under the lower P_{O2}. On the opposite surface under the higher P_{O2}, the grain boundaries rose. Alumina under this testing environment is a p-type semiconductor. Therefore, this unique morphological change may be related to migration of aluminum ion from the lower to higher P_{O2} sides through the cation vacancies which segregate at grain boundaries.

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