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Corrosion Behavior of Sintered YSZ with Volcanic Ash for Thermal Barrier Coatings

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Abstract

In this study, the high-temperature corrosion behavior by volcanic ash was evaluated for sintered yttria-stabilized zirconia (YSZ) used as a thermal barrier coatings (TBCs). To evaluate high-temperature corrosion resistance, real volcanic ash was stacked on the surface of the sintered body at 40 mg/cm^2 and exposed to 1300°C heat for 2, 12, and 48 h. The phase change due to the reaction of YSZ and volcanic ash was characterized using high temperature X-ray diffraction (HT-XRD) at 25°C, 1100°C, 1200°C, 1300°C. As a result of HT-XRD, the t-ZrO_2 phase and $NaAlSi_3O_8$ (Albite) phase were observed at 25°C. However, the $NaAlSi_3O_8$ (Albite) phase disappeared and the m-ZrO_2 and $ZrSiO_4$ phases were analyzed at 1300°C. The results indicated that the chemically reacted with the ZrO_2 and the SiO_2 from molten volcanic ash to form $ZrSiO_4$ connected in a spherical morphology. The thickness of the spherical $ZrSiO_4$ increased with increasing heat-treatment time.

Keywords: YSZ, Thermal barrier coatings, Volcanic ash, Corrosion behavior, Spark plasma sintering

1. Introduction

Thermal barrier coatings (TBCs) are used to protect gas turbine engine hot-section components to meet future high fuel efficiency and low engine emissions targets. The rise in temperature in gas turbine engines creates problems. TBCs are applied to the hot parts of the engine to overcome this demand because their melting temperature is higher than that of the metal parts. The outside of the hot metal parts in gas turbine engines is coated with TBCs, which reduce the base metal temperatures by up to 300°C. These new gas turbine designs are gradually approaching the goal of higher gas-inlet temperatures, improving thermodynamic efficiency to reduce fuel consumption and environmental impact [1–2].

Silicate particles can be produced by various substances, such as volcanic ash [3–6], desert sand, and dust, and can be sucked together into the air [7–8]. In 2010, the eruption of the Eyjafjallajökull volcano in Iceland affected thousands of flights and millions of passengers, resulting in billions of dollars in economic losses [9]. Over the past 20 years, more than 100 commercial aircraft have encountered volcanic ash, and some have been severely damaged. Recently, volcanoes have erupted around the world, including Japan, Australia, and the Philippines. Volcanic eruptions blow ash into the sky. The volcanic ash led authorities to halt all flights to and from airports, causing enormous economic damage. Minimizing TBCs reactivity to volcanic ash can reduce economic stagnation and damage.

For TBCs applications [10–11], 7–8 wt.% yttria-stabilized zirconia (YSZ) is widely used as a coatings material. Generally, 7–8 wt.% YSZ is used as a coatings material for turbine blades due to its excellent thermal properties. However, volcanic ash deposits proceed along the boundary of the YSZ particles, and t-ZrO_2 can crack due to significant volume changes (4–5 V.%) when cooled [12–13]. When the volcanic ash attack becomes severe, ZrO_2 is converted only into spherical particles, which are produced in the process of melting and re-deposition into typical micros spherical

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