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Effect on Self-healing Behavior of SiC Size on $Yb_2Si_2O_7$/SiC Composites for Environmental Barrier Coatings

Seung-Hyeon KIM[1], Toshio OSADA[1] and Byung-Koog JANG[2,*]

[1] *Research Center for Structural Materials, National Institute for Materials Science, 1-2-1 Sengen, Tsukuba, Ibaraki 305-0047, Japan*

[2] *Interdisciplinary Graduate School of Engineering Science, Kyushu University, 6–1 Kasuga-koen, Kasuga, Fukuoka 816-8580, Japan*

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Abstract

Dispersions of SiC (nano) and SiC (micro) are proposed to maintain the $Yb_2Si_2O_7$ matrix and promote crack self-healing for environmental barrier coating (EBC). The high-temperature self-healing behavior of $Yb_2Si_2O_7$/ 20 vol.% SiC (micro, nano) was investigated at temperatures of 1100 and 1300°C for up to 10 h in air. The self-healing effect is affected by SiC size, oxidation time and temperature. The formation of SiO_2 by high-temperature oxidation of SiC particles was analyzed by XRD at 1100°C from 5 h for SiC (micro) to 2 h for SiC (nano). Commonly, surface cracks were fully recovered after heat treatment at 1300°C for 0.5 h in air. Cracks were recovered by volume expansion due to SiO_2 formed by SiC oxidation, and the crack recovery rate increased as the size of SiC (micro, nano) decreased. The self-healing behavior of the $Yb_2Si_2O_7$/20 vol.% SiC composite as a function of SiC (micro, nano) demonstrates that it is worth further investigation as an EBC material.

Keywords: $Yb_2Si_2O_7$, SiC, Self-healing, Oxidation, Environmental barrier coating

1. Introduction

SiC-based ceramic matrix composites (CMCs) are applied as high-temperature structural materials for next-generation gas turbines due to their excellent high-temperature mechanical properties and oxidation resistance [1–2]. In a high-temperature combustion environment, a silica protective layer is formed on the surface of CMCs, and the generated water vapor reacts with the silica protective layer to form volatile silicon hydroxide, shortening the lifespan of CMCs [3–6]. Therefore, an environmental barrier coating (EBC) is applied to increase the durability of the CMCs and protect it from water vapor [7–18].

However, cracks occur on the surface of the EBC itself due to thermal shock and physical impact of fine dust or debris from the combustion section of the gas turbine. Cracks seriously affect EBC durability in a high-temperature combustion environment. To solve this problem, it is to develop structural ceramics with self-healing properties to improve durability [19–22]. In order to maintain the mechanical stability and protective properties of EBC, the cracks formed must be healed [23]. In the case of SiC as a healing agent, the self-healing mechanism is that the cracks are filled by SiO_2, an oxidation product of SiC, and form depending on the oxidizing environment (temperature and time). The following reaction proceeds in a high-temperature steam environment [24–25].

$$SiC(s)+3/2O_2(g) \rightarrow SiO_2(s)+CO(g)\uparrow \quad (1)$$

$$SiC(s)+3H_2O(g) \rightarrow SiO_2(s)+CO(g)\uparrow+3H_2(g)\uparrow \quad (2)$$

$$SiO_2(s)+2H_2O(g) \rightarrow Si(OH)_4(g)\uparrow \quad (3)$$

Recently, rare-earth (RE) silicates have been reported as promising EBC materials [26–28]. In particular, many studies have been reported on $Yb_2Si_2O_7$ because its resistance to water vapor corrosion and coefficient of thermal expansion (CTE) are similar to those of SiC [26,29,30]. However, $Yb_2Si_2O_7$ and other EBC ceramics have low fracture toughness and strength, making

*Corresponding author: jang.byungkoog@kyudai.jp