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Reaction bonding of open cell SiC–Al_2O_3 composites

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Abstract

Based on the reaction-bonding aluminum oxide (RBAO) technology, open cell SiC-Al_2O_3 composites with high strength were fabricated from aqueous slurry by a replication process with polyurethane sponges as the substrates. TGA reveals that about 18 wt% of the initial Al powder in the start compositions oxidized after 1 h stirring. Mixing procedure has a strong effect on the slurry rheological behavior and macrostructure of ceramic foams. The slurry prepared by stirring 1 h has a high viscosity and thixotropic behavior, which makes it uniformly coat the sponge substrate, resulting in the production of a ceramic with a uniform macrostructure. But, due to the emission of a lot of gas arising from the dramatic oxidation of the Al powder during milling, a large number of air bubbles are introduced in the slurry, and this is detrimental to the macrostructure of the ceramic foam. The phase compositions of the samples consist of silicon carbide, alumina, cristobalite, and mullite after sintering at 1350°C with a 1-h hold. Compressive strength increases as the Al powder content increases, and reaches 2.89 MPa with a 12 wt% Al powder for ceramic foams with a relative density of 0.30.

Keywords: A. Composites; A. Ceramics; B. Chemical synthesis; C. Microstructure

1. Introduction

Ceramic foams have many potential advantages, such as high-temperature strength, high resistance to chemical attack, high refractoriness, and good insulating characteristics. These properties make ceramic foams suitable for many applications such as filters, membranes for

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separation, catalyst supports, gas burners, sensors, and thermistors [1]. Ceramic foams already commercially available or in study are made of various materials, following the constraints of specific applications, such as coridierte, mullite, silicon carbide, alumina, partially stabilized zirconia, and some composite systems (SiC–alumina, alumina–zirconia, alumina–mullite, mullite–zirconia) [2]. Silicon carbide has been considered to be one of the best candidate materials for high-temperature filter due to its lower thermal expansion coefficient, high thermal conductivity, and high strength [3,4].

Several typical processes have been developed to produce ceramic foams. These include: (1) the polymeric sponge method [5], which involves impregnation of a sponge by immersing it into a ceramic slip. After removal of the excess slurry and drying, the sponge is burned out and the ceramic material is sintered, resulting in a replica of the original foam; (2) the bubble generation method [1,5], in which a foaming agent is added to the ceramic suspension. By agitation, foam is built up with a pore structure, essentially consisting of the closed pores that may remain after sintering; (3) CVD /CVI coating method [6,7], which involve pyrolysis of thermosetting polymer foam (or polysilane/polycarbosilane) to form a carbonaceous skeleton first and then coat it with various nonoxide ceramics by chemical vapor deposition/infiltration. However, the polymeric sponge method is the most popular approach employed to prepare highly open cell ceramics.

To meet the stringent requirements for some applications, there is a need to develop improved processing techniques to improve the strength of these material. Recently, the reaction bonding of aluminum oxide (RBAO) was successfully developed as a novel technique of fabricating high-strength alumina ceramins. [8,9]. In this technique, attrition-milled Al/Al_2O_3 powder compacts are heat treated in air such that Al oxidizes to small “new” Al_2O_3 crystallites, which sinter and thereby bond together the originally added Al_2O_3 or ceramic particles. The objective of this work is to prepare open-cell SiC/Al_2O_3 composites by the polymeric sponge method. The RBAO technique was exploited to improve the strength of the ceramic foams. Effects of the mixed procedure on the rheology of slurries and macrostructure of RPCs were investigated. The hypothesis that water can be utilized as a mixed medium in the presence of Al powder has been confirmed.

2. Experimental procedure

2.1. Materials

Commercial polyurethane sponges with open porosity of approximately 10 pores per inch were chosen in this study. TG analysis (Shimadzu TGA-50H, Shimadzu Corporation) of the sponge was preformed in air atmosphere at heating rate of 10°C/min. The complete pyrolisis of the sponge was reached before a temperature of 600°C observed from Fig. 1.

A commercial silicon carbide powders (≥97%, 325 mesh) was used as the major material. Alumina powder (α-Al_2O_3, 99.16%, d50 = 0.62 μm) and aluminum powder with globular particles (≥99.7%, 300 mesh, Fig. 2) as sintering aids were chosen. Bentonite was used to improve the rheology of the slurry. A commercial silica sol (26.2%, pH = 9.5–10) was used as a binder, and polyethyleneimine (PEI) was added into the slurry as a thickening agent.