



ELSEVIER

Contents lists available at ScienceDirect

Solar Energy Materials & Solar Cells

journal homepage: www.elsevier.com/locate/solmat

In-situ synthesis and thermal shock resistance of cordierite/silicon carbide composites used for solar absorber coating



Xiaohong XU, Zhenggang RAO*, Jianfeng WU, Yonghua LI, Yaxiang ZHANG, Xinbin LAO

State Key Laboratory of Silicate Materials for Architectures, Wuhan University of Technology, Wuhan 430070, China

ARTICLE INFO

Article history:

Received 7 November 2013

Received in revised form

30 May 2014

Accepted 13 July 2014

Keywords:

Cordierite/silicon carbide composite

Content

Thermal shock resistance

Solar absorptance

Solar absorber coating

ABSTRACT

Cordierite/silicon carbide (SiC) composite ceramics with 10, 20 and 30 wt% cordierite were in-situ prepared via pressureless firing technique using silicon carbide, alumina, Kaolin and talc as starting materials. The results show that the synthesized composites all exhibited the good physical and mechanical properties. Among those, A2 composite with 20 wt% in-situ cordierite fired at 1280 °C exhibited the better bending strength and thermal shock resistance. The improvement of thermal shock resistance could be attributed to the proper cordierite wrapped around SiC, the homogeneous distribution of pores, the well-grown grains, as well as the formation of some glass phase. During the thermal shock test, a small amount of glass phases generated from the oxidation of SiC could react with Al₂O₃ and MgO, and then more cordierite was formed due to the incorporation of nucleating agent TiO₂. With in-situ cordierite content rising, both absorptance and emittance of composite reduced, but A2 composite had the better absorbing ability for the solar energy. It is believed that these in-situ cordierite/SiC composites should be a promising candidate to apply in the field of solar absorber coating owing to the better thermal shock resistance and absorptance of solar energy.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

The high temperature resistance (instantaneous temperature up to 1000 °C) is essentially required for the solar thermal power generation. However, the current coatings still lack the stability and performance desired for moving to higher operating temperatures [1]. Especially, they failed to withstand the repeated thermal shock resulted from the cyclic starting up and shutting down of the system. So, it is essential to develop some novel and desired candidates to use as the solar absorber coating. Fortunately, Silicon carbide (SiC), exhibits many novel and excellent properties such as the superior hardness, good chemical resistance, high values of conductivity, low values of thermal expansion coefficient, as well as the excellent thermal stability and thermal shock resistance [2]. And, SiC had been recognized as a promising candidate material for high-temperature structural applications in heat engines, heat exchangers, and many other devices owing to its excellent high-temperature strength, oxidation and corrosion resistance [3]. In particular, it could be used as the solar absorber coating for the solar thermal collector due to its high absorptance and thermal

conductivity. But, SiC need to be sintered higher than 2100 °C [4]. If introduce fluxes such as potash feldspar and albite to realize low temperature firing, the generated excessive glassy phase would reduce the bending strength and thermal shock resistance of materials.

As known, cordierite (2MgO · 2Al₂O₃ · 5SiO₂) has a lower synthesis temperature, superior thermal stability, thermal shock resistance, low thermal expansion coefficient, along with a low loss of strength above 1000 °C. It is promising that cordierite should contribute to the solution of certain technical problems or meet demands which is only partially satisfied or not at all by other ceramic materials, and hence keep a remarkable role in the field of ceramic materials. Generally, each of the monolithic phased ceramic exhibits a single physical and chemical property only, which highly hinders its applications. Accordingly, to develop the multi-phase ceramics has been attracting more and more attention due to the combinations of the optimal properties of each mono-phased ceramic once added with the proper ratio together. The in-situ synthesized cordierite ceramic, bonded with the SiC matrix to produce the multi-phase cordierite/SiC composite ceramic fired at lower firing temperature, can evidently improve the thermal shock resistance. It was widely reported that the thermal shock resistance of ceramic materials such as alumina [5], mullite [6], silicon carbide [7–9], silicon nitride [10] as well as andalusite

* Corresponding author. Tel: +86 15827316695.

E-mail address: jxrzg86@163.com (Z. RAO).

Table 1
Chemical compositions of raw materials (wt%).

Raw materials	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	TiO ₂	CaO	MgO	K ₂ O	Na ₂ O	SiC	l.L	Total
α-Al ₂ O ₃	0.30	99.18	0.04	0.00	0.03	0.00	0.01	0.08	0.00	0.12	99.86
Talc	56.51	2.11	0.98	0.09	1.31	30.69	0.01	0.02	0.00	7.44	99.82
Silicon carbide	0.19	0.01	0.02	0.00	0.03	0.00	0.01	0.00	99.18	0.15	99.93
Kaolin	48.02	37.84	0.10	0.63	0.07	0.00	0.21	0.00	0.00	12.95	99.62

Table 2
Designed compositions of samples (wt%).

Sample no.	Silicon carbide	Talc	Kaolin	α-Al ₂ O ₃	Total
A1	90	3.97	4.82	1.21	100.00
A2	80	7.95	9.63	2.42	100.00
A3	70	11.91	14.45	3.64	100.00

[11], could be significantly enhanced by the in-situ formed cordierite. Dimitrijevic [8] fabricated the good cordierite/SiC composite with well thermal shock resistance via in-situ firing of Mg-exchange zeolite, alumina, quartz and SiC.

In the present work, Kaolin, talc and alumina were used as starting materials to synthesize cordierite, and then were bonded with SiC matrix to form the cordierite/SiC composite ceramics. Thermal shock behaviors under cyclic quenching of the as-prepared ceramics were investigated, and also the solar absorptance and thermal emittance were discussed in detail. It is expected that this work could contribute to develop and expand the applications of cordierite/SiC multiphase ceramics.

2. Experimental methods

Commercially available SiC powder (~250 mesh, Dongda Industrial Co., Ltd., Henan province, China), Kaolin (~250 mesh, Kaolin Co., Ltd., of China, China.), α-Al₂O₃ (~250 mesh, Shandong Alumina Industry Group Co., Ltd., China), and talc (~250 mesh, Guilin Guiguang Talc Development Co., Ltd., China) are used as raw materials prepare the cordierite/SiC composites, and their corresponding compositions are listed in Table 1. The designed compositions of the samples are listed in Table 2, which contains 90, 80, 70 wt% SiC contents and 10, 20, 30 wt% in-situ synthesized cordierite, numbered A1, A2 and A3, respectively. The mixtures were thoroughly dry-mixed by ball milling. After some pretreatments such as granulating and aging, the mixed powders were pressed into the cylindrical green body (Φ30 × 5 mm) at 60 MPa pressure and the cubical green body (37 × 6.5 × 6.5 mm) at 50 MPa pressure by using uniaxial pressing machine (Model NYL-500, Wuxi machine factory, China) and 5 wt% polyvinyl alcohol solutions as binder, respectively.

The pressureless firing of compacts was fired from 1200 °C to 1320 °C with an interval of 20 °C with a hold period of 3 h. In the thermal shock resistance experiment, the specimens were heated up from room temperature to 1000 °C with 5 °C/min rate and held for 15 min in the furnace. Afterwards, the specimens were cooled down in air from 1000 °C to room temperature, and then returned the furnace to heat up to the designed temperature again. When several cycles were completed, the residual strength of specimens was tested to evaluate the thermal shock resistance.

The phase composition of the composites were identified by X-ray diffractometer (XRD) (Model D/Max-III A, Rigaku., Japan). Elemental analyses were performed using an Electron Probe Microanalyser (EPMA) (Model JXA-8230, Jeol, Japan). The microstructures of the fractured surface of the as-prepared ceramics were

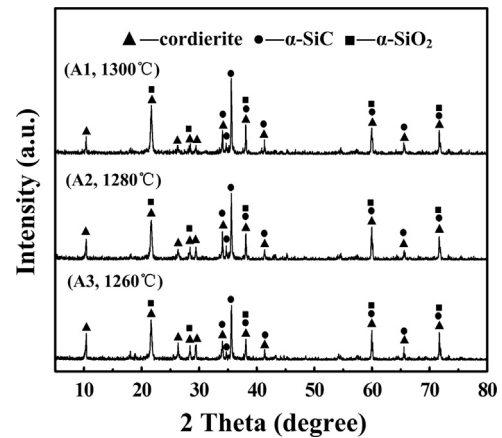


Fig. 1. XRD patterns of A1, A2 and A3 samples fired at different temperatures.

observed by scanning electron microscope (SEM) (Model JSM-5610LV, Jeol., Japan). The pore diameter distribution of samples was calculated by Image-Pro Plus (Model IPP6.0, Media Cybernetics, America). The water absorption (*W_a*), apparent porosity (*P_a*) and bulk density (*D_b*) of the composites were measured by the Archimedes Method. The bending strength of the composites before and after thermal shock was determined by a computer-controlled electronic universal testing machine (Model RGM-4100, Shenzhen Reger Instrument Co., China). The thermal expansion coefficient of the composites was tested by thermal dilatometer (Model WTC, Wuhan University of technology, China). The Solar absorptance (α) and thermal emittance (ε) of the cordierite/SiC composites were measured by UV-vis-NIR spectrophotometer (Model UV-3600, Shimadzu, Japan) and infrared spectrometer (Model Tensor 27, Bruker optics, German).

3. Results and discussion

3.1. Phase identification and microstructure

Fig. 1 shows the XRD patterns of A1–A3 composites. Fig. 2 is the elemental analyses of fracture surface of A2 sample fired at 1280 °C. It is believed when ranging of 1260–1300 °C, cordierite could be favorably in-situ formed via the in-situ reaction of α-Al₂O₃, talc and Kaolin, and cordierite/SiC composite ceramics could be synthesized completely. As a matrix phase, SiC is observed evidently. However, a tiny of α-SiO₂ phase is also identified in the XRD level, meaning the incomplete conversion reaction of system. Moreover, with the firing temperature increasing, the peak intensity of cordierite phase slightly reduced. The above conclusions can be verified by the semi-quantitative analysis of series A fired at different temperatures shown in Table 3. The increase of in-situ synthesized cordierite is attributing to the increasing amount of Kaolin, talc and α-Al₂O₃ in the in-situ reaction system.

Figs. 3 and 4 show the microstructures of fracture surfaces for A1, A2 and A3 composites fired at 1260 °C, 1280 °C and 1300 °C, respectively. As seen, the crystal growth more completely when

Download English Version:

<https://daneshyari.com/en/article/6535559>

Download Persian Version:

<https://daneshyari.com/article/6535559>

[Daneshyari.com](https://daneshyari.com)