A study on thermal property differences between SiC/C FGMs and non-FGMs by Chemical Vapor Deposition

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Introduction

Graphite and C/C composite have a excellent thermal shock resistance: however, they start to oxidize above 500℃ and rapidly oxidize over 900℃ under air atmosphere. SiC has a high oxidation resistance and a high flexural strength at high temperature. Sintered SiC is not easily produced by general sintering methods. To combine the good thermal properties of the both materials, SiC monolithic coating on carbon was suggested.

SiC monolithic coating on carbon could not withstand on the severe thermal condition such as re-entry of space suttle. In order to overcome this situation, the idea of FGMs having a compositional gradient from one surface to the other has been proposed. In this study, the thermal properties of SiC/C FGMs and non-FGMs are compared through thermal shock test, thermal fatigue test and thermal conductivity measurement.

Experimental procedure

Propane was used as C-suppling source and $SiCl_4$ was used as Si-suppling source. H_2 and Ar were used as carrier gas and atmosphere gas, respectively.

The CVD apparatus used in this experiment was the horizental hot-wall type.

XRD, SEM/EDS and XPS were used for the characterization of the deposited layer.

The deposition temperature was fixed at 1300℃ and total pressure of the reactant tube was about 10~50 torr.

Thermal cycling test was performed by using halogen image furnace. The schematic diagram is shown in fig. 1. As shown in fig.1, the infrared rays irradiated from halogen lamp were focused on the surface of the specimen. The surface of the specimen was heated to 1600℃ and cooled to room temperature by the cooling water. The time interval for thermal cycling test was 10 minutes. Each specimen went through 30 times for thermal cycling.

Thermal shock test was performed by using vertical tube furnace. Being heated to 1500℃, 1400℃, 1300℃, 1200℃ and 1100℃, each specimen was dropped into the ice water or liquid nitrogen, then observed with microscope.

Thermal conductivities were obtained by measuring the thermal diffusivity of specimen.

The one side of thin sample was heated and AC temperature amplitude was detected in thermocouple which was fixed on the other side. Thermal conductivity was calculated through AC temperature amplitude measurement and the various formula.

Results and Discussion

SiC/C FGMs having the various step morphologies were prepared in C_3H_8-$SiCl_4$-H_2-Ar systems by controlling the input gas ratios.

Fig. 2 shows the surface of SiC/C FGMs and non-FGMs after thermal cycling test under the same condition of $\triangle T$=1600℃. No crack was found on the surface of SiC/C FGMs. The similar results were obtained in case of the thermal shock test. Cracks were found on the surface of SiC/C non-FGMs at $\triangle T$=1200℃, whereas no crack was found on the surface of SiC/C FGMs at $\triangle T$=1500℃.

Table.1 shows the results of thermal conductivity test. Stepwise SiC/C FGMs have good thermal barrier characteristics in comparison with SiC and graphite. However, their mechanica l strength would be very low because of existance of porous layers and lack of good adhesion between steps.

It can be concluded that SiC/C FGMs have much better thermal properties than those of non-FGMs.

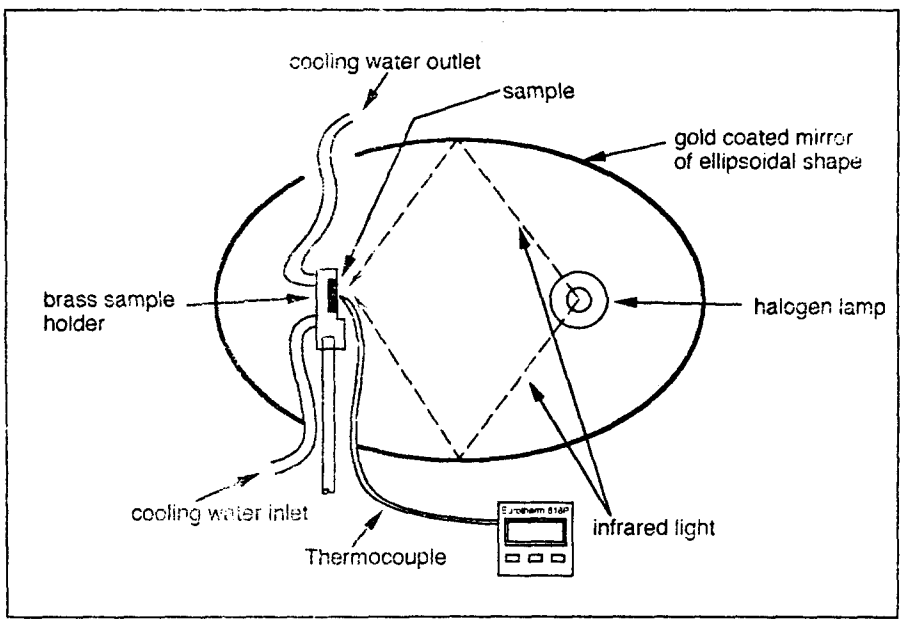

Fig. 1 Shematic diagram of halogen image furnace for thermal cycling test.

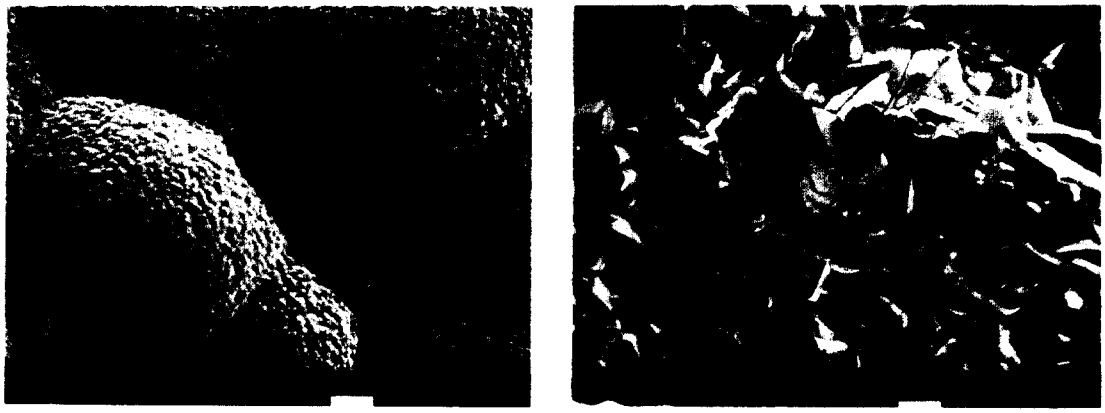

Fig. 2 SEM micrographs of SiC/C FGMs and SiC/C non-FGMs after thermal cycling test
(a) SiC FGMs (b) SiC non-FGMs

sample type	frequency(Hz)	thermal diffusivity (cm^2/s)	thickness (μm)	thermal conductivity (J/cm · s℃)
Graphite	5	0.870	236	1.116
stepwise FGMs	6	0.522	230	0.718
semi-continuous FGMs	3	0.970	115	2.836
SiC (non-FGMs)	5	1.156	50	3.150

Table. 1 The results of thermal conductivity test