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A Modern & Unique Approach for Fabrication of Reaction Bonded Silicon Carbide Composites Applied in USM

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Abstract: *Reaction bounded silicon carbide(RBSC) composites are fully dense materials fabricated by pressure-less infiltration of molten silicon into compacted mixtures of silicon carbide and carbon. Free carbon is formed as a result of the pyrolysis of an organic resin, (the carbon source) and reacts with molten silicon to form secondary SiC grains that precipitate on the original SiC particles. Non-reacted residual silicon fills the free areas between the SiC grains. The presence of the residual silicon decreases the mechanical properties of the composites; moreover, the pyrolysis process is environmentally unfriendly. In the present study. Boron carbide powder was used as an alternative carbon source, leading to reduced fraction of the residual silicon. In addition, the volume available for the infiltrated silicon was reduced by using mixtures of multimodal silicon and boron carbides powders and thereby obtaining a relative density of about 80% in the compacted body. The final composites fabricated by infiltration with molten silicon, that has optimal composition display a relatively low fraction of residual silicon and improved mechanical properties (hardness 1960±300HV, elastic modulus 315±2GPa, flexural strength 291±15 MPa). It is also noteworthy that the suggested approach is environmentally friendly. The use of the new composites in Ultrasonic machining(USM)is discussed in this paper*

Keywords: *Sic, USM, Boron, organic resin*

I. Introduction

RBSC is an alluring material for light protective layer applications. A routine approach of RBSC manufacture includes penetrating a compacted SiC/carbon blend with liquid Si. The response between liquid silicon and free carbon prompts to the development of silicon carbide grains, which encouraged on the underlying SiC particles, interconnect them, and give nonstop artistic skeleton. The run of the mill microstructure of RBSC composites comprises of the around 85% between associated silicon carbide stage and lingering silicon .

The fundamental preferred standpoint of the RBSC manufacture process is it's moderately low temperature (~1500°C) in examination with weight less or hot squeezing densification. Then again, RBSC composites have two primary issues. The first is the nearness of the leftover silicon that prompts to bringing down mechanical properties of the last composites and the second one is identified with utilizing carbon containing organics (tars) as a wellspring of free carbon, which is framed as an aftereffect of a pyrolisis procedure. This procedure happens at raised temperatures and went with discharging lethal gasses and is emphatically earth disagreeable. So as to decrease the measure of the remaining silicon in response fortified composites it was proposed to utilize powder blend with suitable particles estimate circulation. This approach permits to create compacts with green thickness of around 20vol. % and to diminish essentially the measure of the remaining silicon (<10vol. %). In our past work was likewise settled that boron carbide specifically responds with fluid silicon and serves as carbon source in the response reinforced boron carbide composites. In the present work we have consolidated these two components to create RBSC composites with diminished measure of the leftover silicon and utilizing boron carbide as an option wellspring of free carbon rather carbon containing organics.

II. Experimental Procedure

Fabrication of the Composites

A Commercially coarse (~120µm) silicon carbide powder was granulated and sieved so as to acquire asked for molecule estimate circulation in the powders blends. A portion of the divisions in the SiC powders blends were supplanted by boron carbide powders with various molecule measure. Boron carbide powder (~1µm, review HS) was provided by H.C. Starck, and B4C powders with normal molecule size of 13µm was provided by "Modan Jang" a Chinese Company. 5 blends of silicon and boron carbides powders were readied and every blend compares to the sought molecule estimate appropriation (Table 1).

Table 1. The powder compositions and particle size distribution that were used at this work

	Particle size, D^{50} ,μm	Vol. % of different powders				
		RB-1	**RB-2**	**RB-3**	**RB-4**	**RB-5**
SiC	**106**	53	53	53	53	53
	50	10	10	10	10	10
	13	18	18	12	7	2
	3	19	4	0	0	0
B_4C	**106**	0	0	0	0	0
	50	0	0	0	0	0
	13	0	0	6	11	16
	3	0	15	19	19	19
Porosity of green compact , %Vol.		24	23	24	24	21

The mixtures were dry mixed in a planetary mixer for 9 hours. 20mm diameter and 8mm high performs were uni-axially compacted under 160MPa. The compacts were infiltrated with liquid silicon (98.3%, Alfa Aesar) at 1480^0C for 15 min under vacuum 10^{-4} torr.

III. Characterization

Microstructure and composition

The microstructure of the examples was examined utilizing optical magnifying lens (OM, Zeiss Axiovert 25) and checking electron microscopy (SEM, JEOL-35) went with a vitality dispersive spectrometer (EDS). The examples for the microstructure portrayal were readied utilizing standard metallographic strategy that incorporates a last phase of cleaning by 2.5μm jewel glue. Picture investigation utilizing the Thixomet programming was connected with a specific end goal to decide the measure of the lingering silicon in the composites. The stage piece was resolved subjective by x-beam diffraction (XRD).

Mechanical properties

Miniaturized scale hardness qualities were dictated by Vickers hardness (Buehler-Micromet 2100) with 2000gr load. Flexural quality was measured with LRX in addition to LLOYD machine (Lloyd Instruments, Fareham Hants, U.K.) utilizing 1.5x2x20mm3 examples. The versatile modulus of the composite was gotten from ultrasonic sound speed estimations as per the "Beat Echo" strategy. Thickness of the invaded composites was measured utilizing Archimedes standard.

IV. Results And Discussions

Microstructure

The microstructure of the composite (Fig. 1) created with expansion of 35%vol. boron carbide powders comprises of B12(C, Si)3, SiC and the leftover silicon. The nearness of the B12(B,C,Si)3 grains with a dim shading somewhat lighter than a shade of SiC particles are plainly watched. It is essential to call attention to that B12(B,C,Si)3 grains associate fired particles and give nonstop earthenware skeleton, like that for the composites manufactured with free carbon increments and its development is in a decent concurrence with the reported already our outcomes for response reinforced boron carbide composites[3].

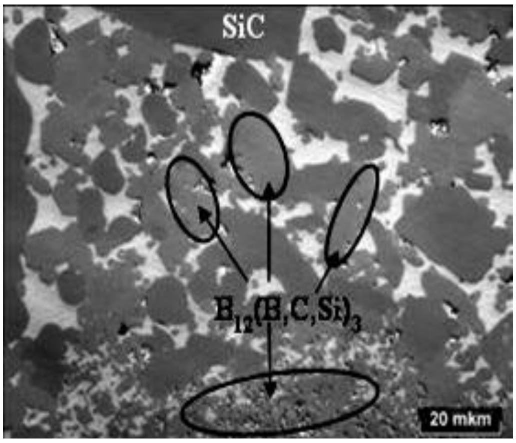

Fig.1. Optical microscope images of the composites microstructure with 35% Vol. B_4C particles (the whole B_4C original particles converted to rim)

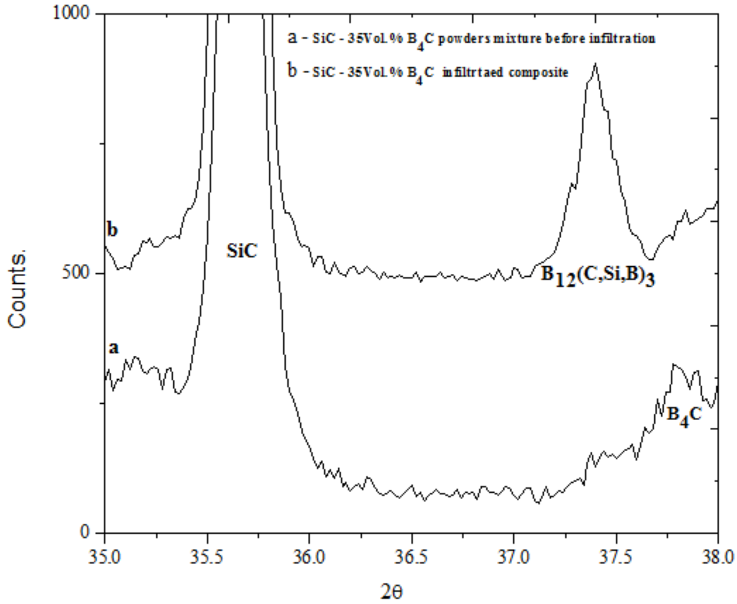

Fig.2. XRD pattern of the composites

As indicated by XRD investigation (Fig. 2) the underlying boron carbide particles (bend a) were totally changed over to the ternary B12(B,C,Si)3 stage (bend b).

It was set up in our past work that in the response fortified boron carbide composites manufactured without free carbon increments the auxiliary SiC stage shows plate-like morphology . Interestingly, for the response fortified SiC, created with boron carbide as the carbon source, the nearness of optional SiC stage with plate-like morphology was not watched. This distinction might be ascribed to the way that surface of the underlying SiC particles, serves as a favored site for heterogeneous SiC nucleation. The nearness of a thick optional SiC layer demonstrates that boron carbide particles serve as a viable wellspring of carbon.

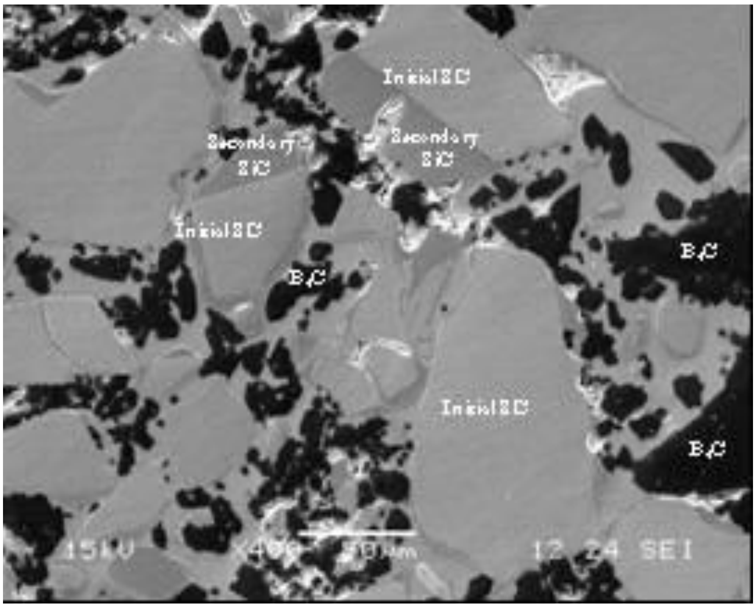

Fig.3. SEM images (SE) of the composites microstructure with 35%Vol. B_4C particles addition

Mechanical Properties

The mechanical and the physical properties of the composites that were fabricated with different fraction of B_4C were summarized in Table 2.

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Table 2. Properties of the infiltrated composites

	RBSC*	RB-1	RB-2	RB-3	RB-4	RB-5
Density , gr/cm^3	2.85-3.10	2.92	2.89	2.89	2.83	2.83
Young's Modulus, GPa ±3	320-340	344	343	345	351	353
Flexural strength , MPa ±18	190-250	204	255	256	237	270
Hardness, Hv	1500-2200	1534±202	1673±262	1835±262	1928±307	1963±331
Residual Si, vol. %	15-35	23.4	19.4	15.6	12.0	10.6

*Range of the composites properties reported in literature**Error! Bookmark not defined.**.

According to the results presented in Table 2 the density of the composites decreasing with the added amount of boron carbide. The enhanced amount of SiC and the reduced amount of the residual silicon stand behind the increased hardness values. As was expected the values of Young modulus do not depend on the particle size of added boron carbide and increases with boron carbide volume fraction. In order to estimate the reliability of the composites, Weibull modulus (m) for flexural strength was calculated according to equation:

$$\ln\ln\left(\frac{1}{1-P}\right) = m\ln\sigma_{\max} - m\ln\sigma_0^{*}$$

Where, $P = \dfrac{i-0.5}{N}$, "i" is the specimen number from N samples, $\sigma_{\max}$ is the flexural strength of specimen *i and* σ_0^{*} is mean value of the flexural strength.

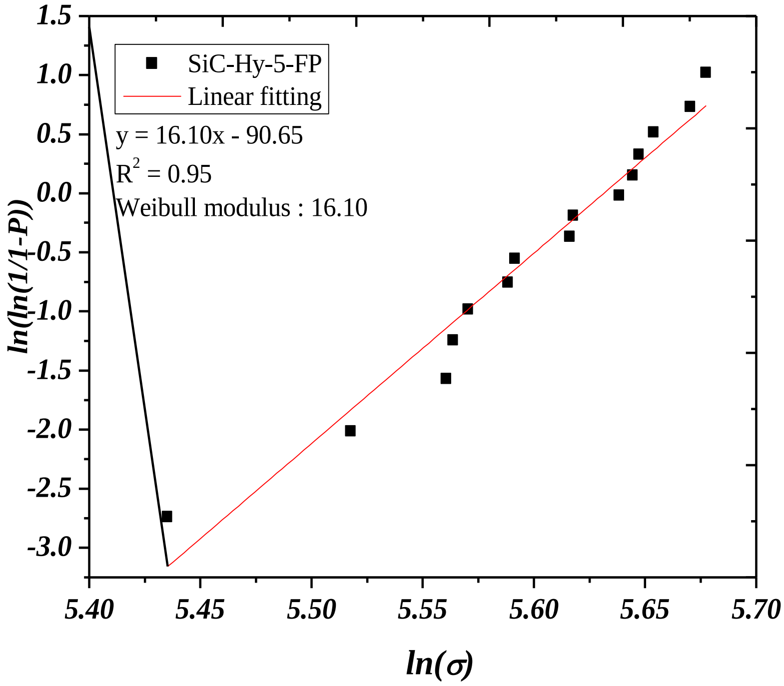

Fig.4. Weibull plots for flexural strength of composites fabricated with 35% vol. B_4C

The outcome of the experimental results treatment for the composites with 35vol. % carbide particles is presented in **Error! Reference source not found.**. The higher value of Weibull modulus for the composites fabricated by using B_4C powder reflects high level of the microstructure homogeneity.

V. Conclusions

RBSC composites were fabricated using various fractions of boron carbide as an alternative source of carbon. The composites with B_4C addition display high reliability and slightly better mechanical properties than the composites fabricated by conventional approaches. The suggested approach is environmentally friendly and allows avoiding the formation of carbon containing organic materials. The applications of this type of composites are effectively tested with Ultrasonic machining.

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