MICG Midlands Industrial Ceramics Group

Midlands Advanced Ceramics for Industry 4.0

CASE STUDY

REF No: 2506004

WS4 - Joining and Repair

FEASIBILITY OF FLASH JOINING OF SIC-SIC COMPOSITES

MODELLING & DESIGN | RAW MATERIALS PROCESSING | FORMING | DRYING & SINTERING | ANALYTICAL

INTRODUCTION

SiC-SiC composites (Silicon carbide matrix with silicon carbide fibers) have a wide range of potential application spaces from aerospace to nuclear fusion. Most applications of SiC-SiC require a method of bonding SiC-SiC to similar (monolithic silicon carbide) or dissimilar materials (i.e tungsten, titanium). The challenging environment of nuclear fusion puts addition constraints on the methods and materials that can be used to bond SiC-SiC. Some successful results have been published on using spark plasma sintering (SPS) machines with rare earth interlayers [1]. Lucideon has developed a versatile flash bonding rig that can be used under both high voltage, low current or high current, low voltage. The furnace can achieve 1600°C, with mechanical pressures up to 80 MPa on a 20 mm^2 sample. A preliminary study was conducted to determine if it would be possible to mimic the SPS results with the flash bonding rig. This was comprised of impedance analysis to determine the frequency-dependent impedance of samples from room temperature to 1500°C.

RESULTS

Particular attention was paid to the set-up as many factors can affect the bonding strength.

Surface roughness: samples were provided by UKAEA with and without rare earth interlayers and using two different polishing methods. White light interferometry was used to determine the surface roughness with results showing that both methods resulted in a surface roughness of 0.1 - 0.2 µm.

Oxidation: Argon was used to flush the furnace of oxygen to minimize SiC oxidation., The oxygen concentration inside the flash bonding furnace was assessed as a function of temperature and argon flow rate. The furnace was found to be slightly better sealed at 1200°C than at lower temperatures, presumably due to thermal expansion. The optimal conditions were found to be 1200°C and argon flow rate of 7 L min^{-1} to keep the oxygen level at 2 ppm.

Preliminary impedance analysis was used to determine the frequency-dependent impedance of samples from room temperature to 1500°C and therefore assess the required current to heat up the samples to the target temperature of 1900°C. The electrical impedance was found to be independent of frequency between 1 Hz and 1 MHz for all samples with samples having an overall resistance of at least 0.4 ohm over the whole temperature range (RT to 1500°C). 0.4 ohm is sufficient to heat a sample to the required 1900°C [1] with the currents available to the flash bonding rig.

Samples were loaded into the flash bonding rig as shown in **Figure 1** and 11.2 +/- 2.8 MPa of uniaxial pressure applied using an automatic pressure-regulating pump.

Bonding between samples was assessed qualitatively, with samples showing good adhesion between the SiC-SiC and interlayer. In particular, one of the tested samples was found to be well bonded (unable to be separated by hand) upon removal from the furnace **(Figure 2),** despite the uniaxial pressure being 5 times lower than that used in [1] and no bonding current being applied.

CONCLUSION

The preliminary impedance and residual oxygen study indicates that our flash bonding rig is suitable for joining SiC-SiC samples.
Furthermore, the interlayer material shows a tendency to bond even at very low pressures and zero bonding current.This material system is therefore an excellent choice for exploring advanced current control algorithms for flash bonding using our versatile high speed controller.

Figure 1

Labelled image of SiC-SiC composite loaded into flash bonding rig

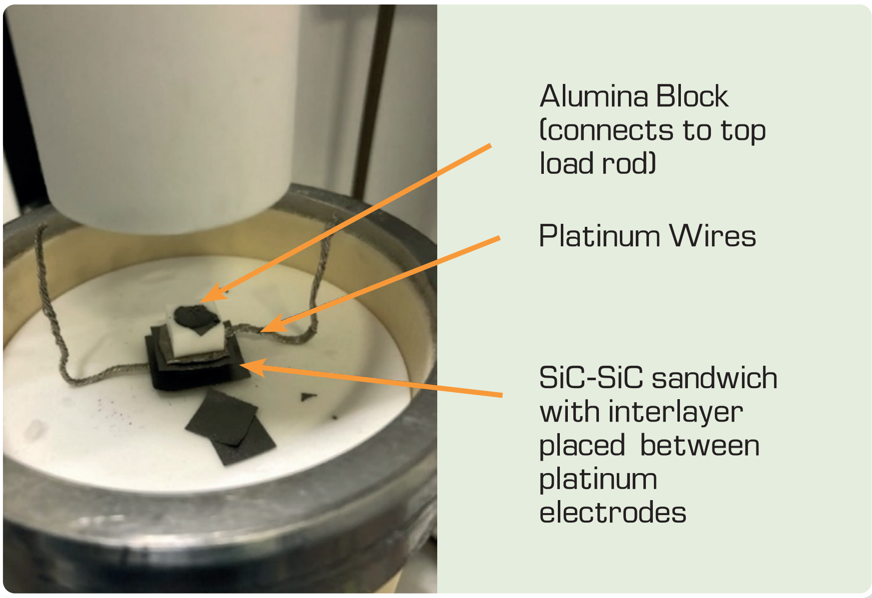
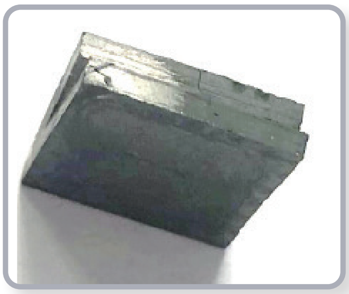


Figure 2

SiC-SiC bonded with interlayer even with no current application.



References
[1] X Zhao, J Liu, et al., “Almost seamless joining of SiC using an in-situ reaction transition phase of Y3Si2C2,” J. Eur. Ceram. Soc., 40 (2020), pp. 259-266.

Contact Details
Christopher Green
Senior Electrical Design Engineer
Christopher.Green@uk.lucideon.com

UK Research and Innovation

The AMRICC Centre

LUCIDEON

This work was supported and partly funded by UK Research and Innovation through the Strength in Places Fund Programme. Midlands Advanced Ceramics for Industry 4.0