

## Midlands Advanced Ceramics for Industry 4.0

# CASE STUDY

REF No: 2506003

## WS7 - Scale up OPTIMIZATION OF REACTIVE MELT INFILTRATION PROCESS FOR REACTION BONDED SiC

MODELLING  
& DESIGN

RAW  
MATERIALS  
PROCESSING

FORMING

DRYING &  
SINTERING

ANALYTICAL

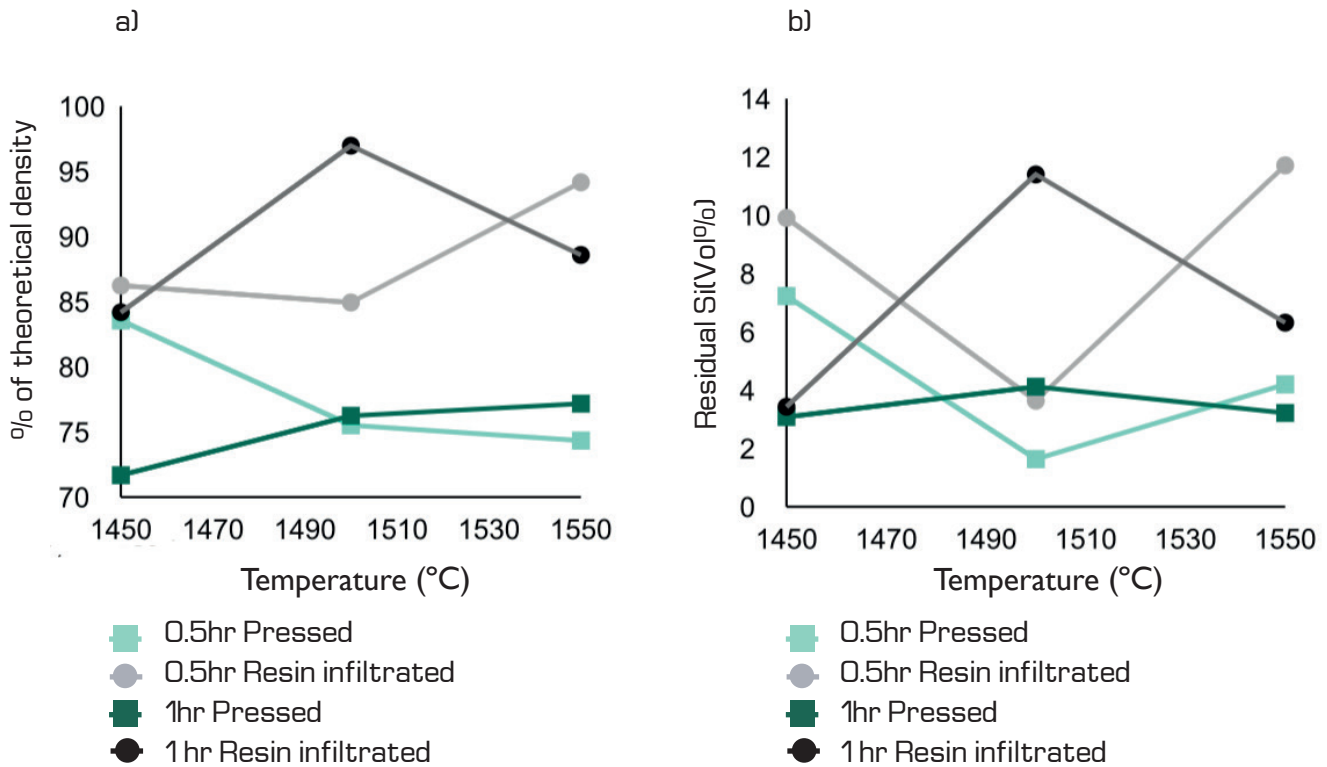
### THE CHALLENGE

As the aerospace and defence industries continue to push the boundaries of speed and power, materials such as silicon carbide (SiC) are gaining attention due to their high hardness, abrasion resistance, and thermal stability. SiC retains its exceptional mechanical properties, including high hardness and stiffness, even at elevated temperatures. Beyond aerospace, SiC is also widely used in various sectors, including electronics, automotives, refractory materials, and industrial applications, due to its unique combination of properties. However, producing SiC poses challenges. Conventional sintering of SiC requires temperatures up to 2200°C and the addition of sintering aids, which often results in inconsistent densities and grain growth issues, impacting the mechanical properties. Liquid silicon infiltration (LSI) offers rapid, cost and energy efficient manufacturing of SiC; as well as scale up opportunities compared to current conventional methods such as pressure less sintering and hot pressing.

LSI offers an alternative manufacturing route by utilizing a solid-melt reaction. This process involves infiltrating a carbon preform with molten silicon, which reacts with carbon to form SiC. LSI requires relatively low processing temperatures, just above the melting point of silicon (1414°C), making it more efficient than conventional sintering methods (1900- 2200°C). For high-temperature applications, it is critical that the amount of residual unreacted silicon in the product is minimised (<5 vol.%). To achieve this both the carbon - silicon carbide preform and the furnace parameters must be optimised. Additionally, the infiltration technique is an aggressive process with molten Si being very volatile and reactive, leading to potential degradation of the furnace lining. As a result of the risk to the furnace, stringent process controls must be developed and applied to ensure the process is safe, sustainable, and economical.

# WHAT WE DELIVERED

The project involved a comprehensive study of the infiltration process conditions, ensuring the protection of equipment and minimising the risk of unwanted reactions with silicon vapor.



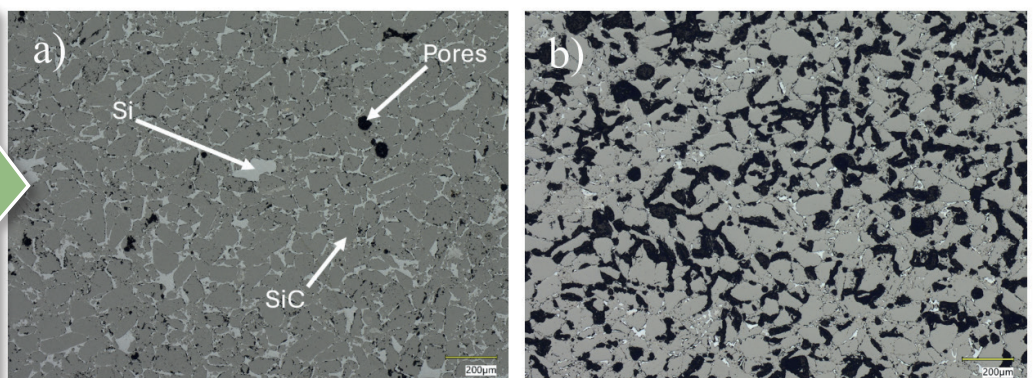
**Figure 1** (a) Theoretical density vs temperature for different preforms.  
 (b) Residual Si content in preforms from microstructure phase fraction analysis vs temperature.

For the experiments two types of preforms were used, one with a carbon source of carbon black in a powder blend that was then pressed and the other using phenolic resin infiltrated into a ceramic green body that was then pyrolyzed to produce carbon. As seen in figure 1, preforms produced with phenolic resin infiltration resulted in greater theoretical densities being achieved over pressed preforms, and this trend was observed consistently through the project. For a 1 hour dwell the percentage of the theoretical density peaked at a temperature of 1500°C with open porosity values of the resin infiltrated samples being as low as 1%. Further optimisation of preforms is needed as large pores were filled with unreacted silicon as can be seen in figure 2a). The most effective infiltration was observed when using a resin infiltrated preform at a temperature of 1500°C and a dwell of 1 hour.

**Figure 2**

(a) Microstructure of sample produced with resin infiltration and an LSI at 1500°C for 1 hour.

(b) Microstructure of sample produced with resin infiltration and an LSI at 1500°C for 30 minutes.



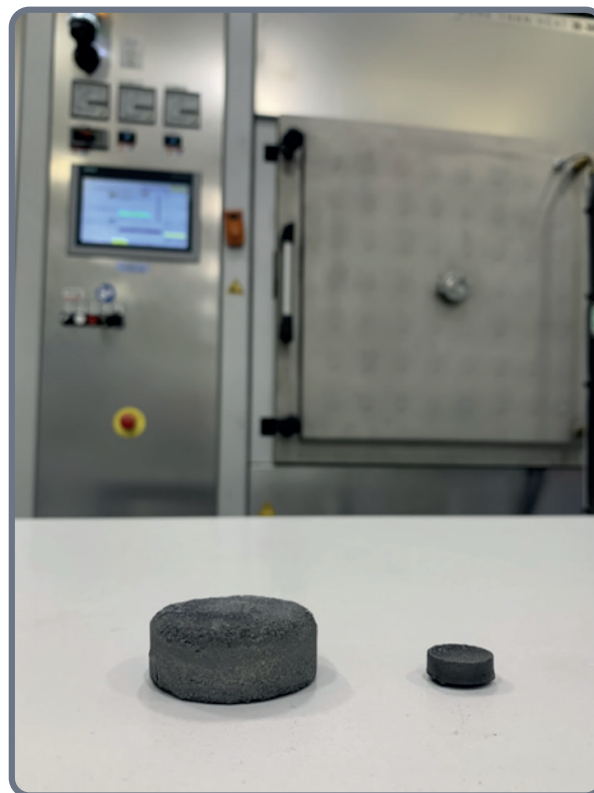
Through this project, Lucideon has identified processing parameters to produce highly dense reaction bonded silicon carbide (RBSiC). Achieving an open porosity of ~1% and theoretical density of 98%, with other samples achieving a residual Si content of ~2%, as can be seen in figure 2. This is comparable to RBSiC reported in literature.

## IMPACT

The project provided valuable insights into preform preparation, including the use of phenolic resins as a carbon source and their pyrolysis behaviour. These processes enable the production of highly carbonaceous preforms that can be infiltrated with silicon to create near-net-shape ceramics.

The risk of silicon attack to the furnace is understood and managed. The graphite retort showed signs of corrosion after performing LSI on 50mm discs, however the use of the retort is enough to protect the rest of the furnace lining from damage. Lucideon is now able to offer liquid silicon infiltration as a service through the AMRICC Centre and has technical expertise in preform preparation for reaction bonding of materials. The skills developed are not only beneficial in the production of monolithic ceramics but also Ceramic Matrix Composites (CMCs).

**Figure 3**  
RBSiC 50mm  
and 20mm  
pellets in front  
of vacuum furnace  
used for LSI.



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