Silicon carbide production from nano silica for B_4C-SiC nanocomposite armours

H.A.Payne, F.Giuliani, L.J.Vandeperre , Imperial College London, UK
Henry.payne15@imperial.ac.uk

Motivation

Modern warfare is developing rapidly; technology is becoming more advanced and the modern soldier requires more of it. This increase in equipment is seeing an increase in weight which reduces mobility. Modern threats have also developed leading to the call for greater personnel protection. Combining these two results in a need to produce lighter, better performing armours.

Materials

Boron Carbide (B_4C) has shown great potential for use in armours. It has a high hardness and low density, but unfortunately it sometimes fails prematurely. This has been explained by a phase transformation involving polytype collapse. This research aims to mitigate structural breakdown by microstructural design. It is hypothesised that the inclusion of nano Silicon Carbide (SiC) grains, produced from Silica (SiO_2) nanoparticles, into the B_4C will reduce amorphous breakdown. This will stabilise the B_4C and hence increase ballistic performance whilst maintaining lightness.

Method

Microemulsion Production

Nanoparticles are produced utilising a Water In Oil (W/O) microemulsion; water droplets are first dispersed in oil forming an emulsion. TEOS and water then react at the droplet surface to form a SiO_4 monomer. The small droplet size limits the number of SiO_4 monomers produced per droplet. These then react together forming nanoparticles. Reaction 1 describes the overall reaction that is occurring and Figure 1 shows the microemulsion process.

$$Si(OC_2H_5)_4 + 2H_2O \rightarrow SiO_2 + 4C_2H_5OH \qquad (1)$$

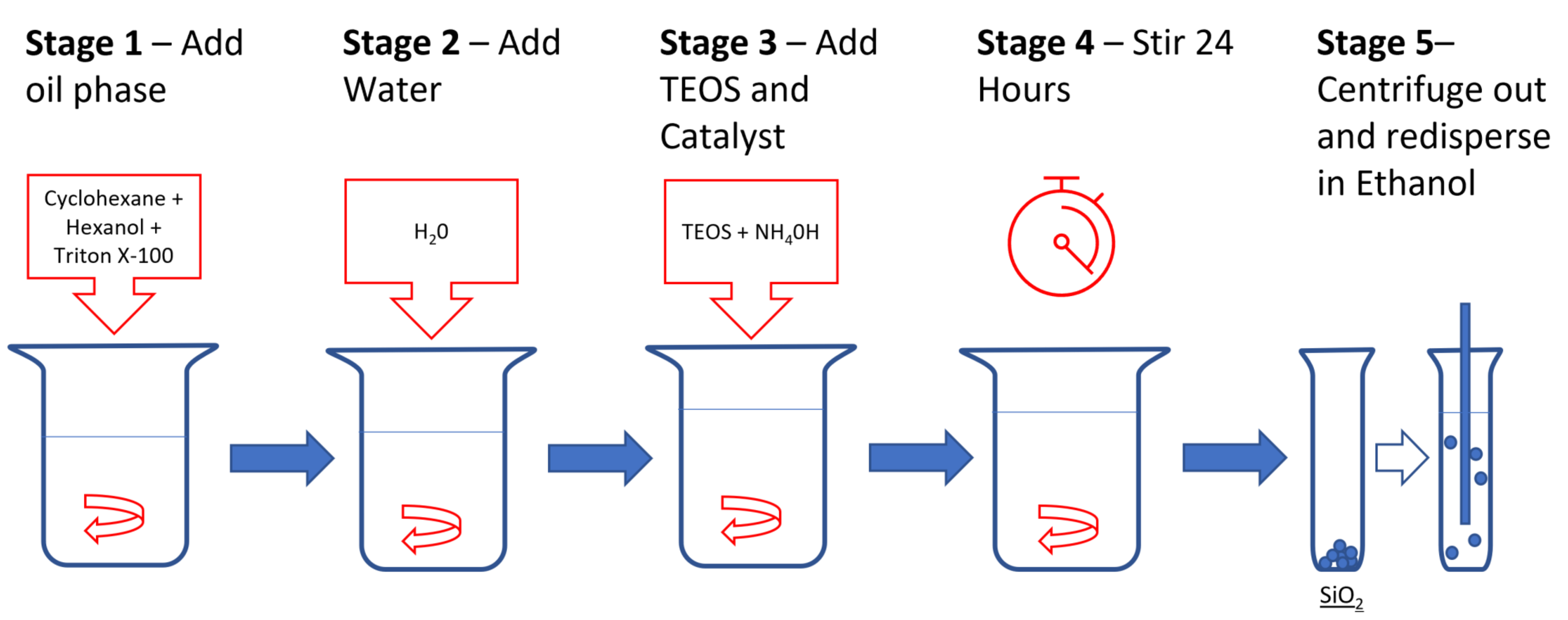

Figure 1: Diagram describing the W/O microemulsion process

SiO_2 analysis and SiC formation

SiO_2 particles must be thoroughly analysed before the reaction to form SiC. This allows the properties of the particles to be linked to the resulting SiC and hence the SiC can be tailored for armour use. The schematic below describes how Secondary Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Dynamic Light Scattering (DLS), Thermal Gravimetric Analysis (TGA) and X-ray Diffraction (XRD) are used to achieve this goal. A heat treatment of SiO_2 with Carbon up to 1580˚C is conducted to form SiC as per Equation 2. The SiC is then mixed with B_4C to form a composite.

$$SiO_2 + C \rightarrow SiC + CO_2 \ (2)$$

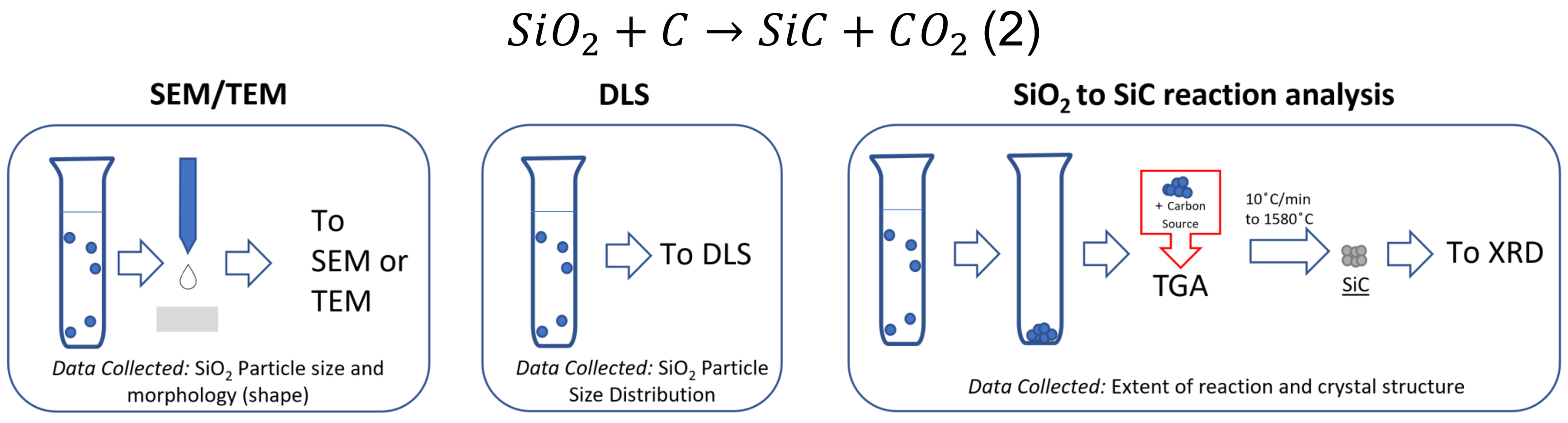

Figure 2: Diagram describing the SiO_2 to SiC process including key analytical stages

Results

Microemulsion Production

SiO_2 particles can now be produced reliably at a mean size (d(0.5)) value of around 100 nm with a standard deviation (σ) of around 70 nm. Figure 3 shows a typical size distribution whilst Figure 4 shows the spherical morphology.

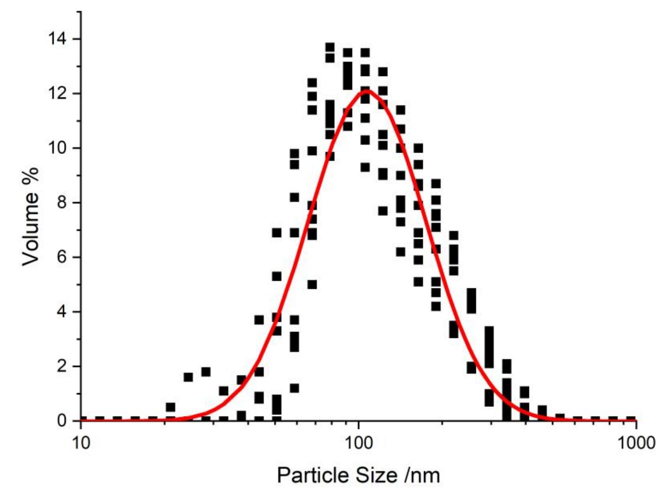

Figure 3: A typical particle size distribution identified using DLS.

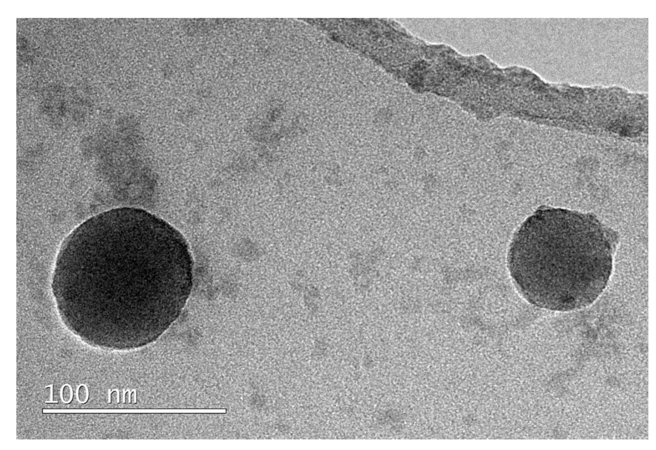

Figure 4: TEM micrographs showing SiO_2 nanoparticles.

SiC Formation

SiC production is clearly seen in Figure 5. Amorphous SiO_2 initially appears as a hump in the XRD pattern. After heat treatment, the amorphous hump is reduced and crystalline peaks linked to SiC appear. Figure 6 shows the change in B_4C-SiO_2 powder as it forms B_4C-SiC powder.

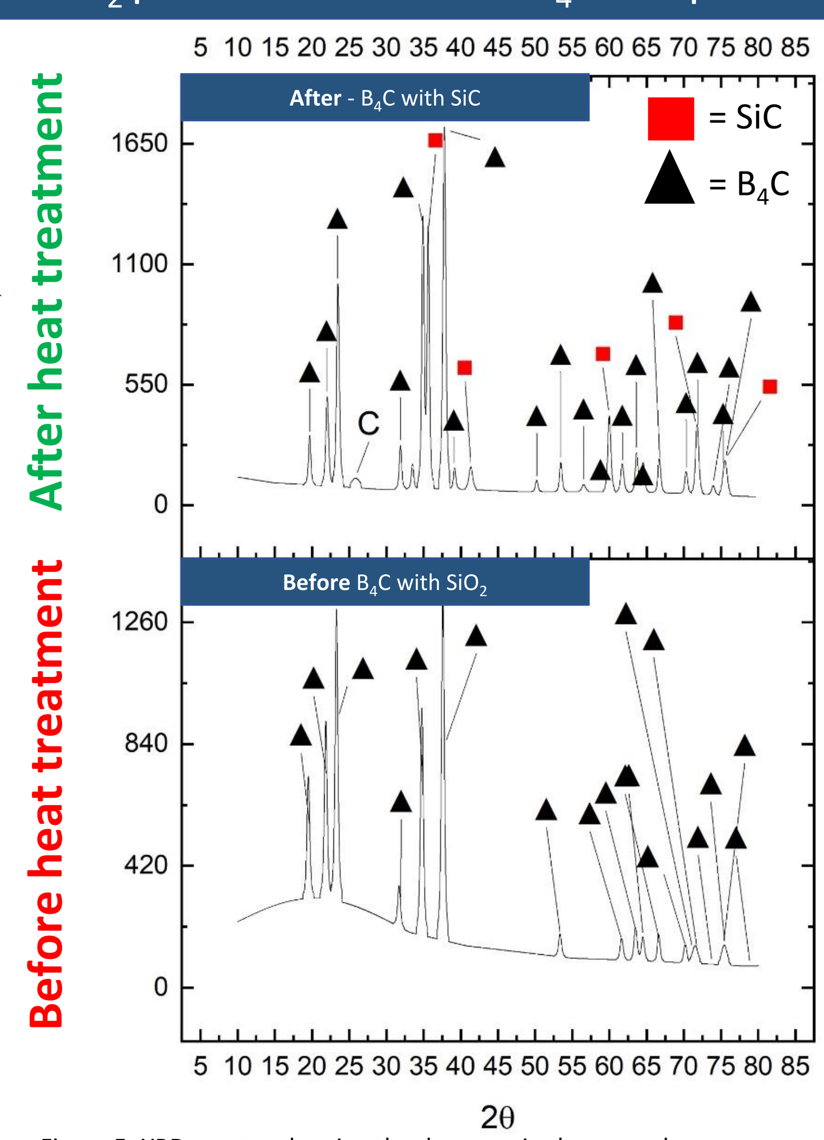

Figure 5: XRD spectra showing the decrease in the amorphous hump and SiC formation after heat treatment.

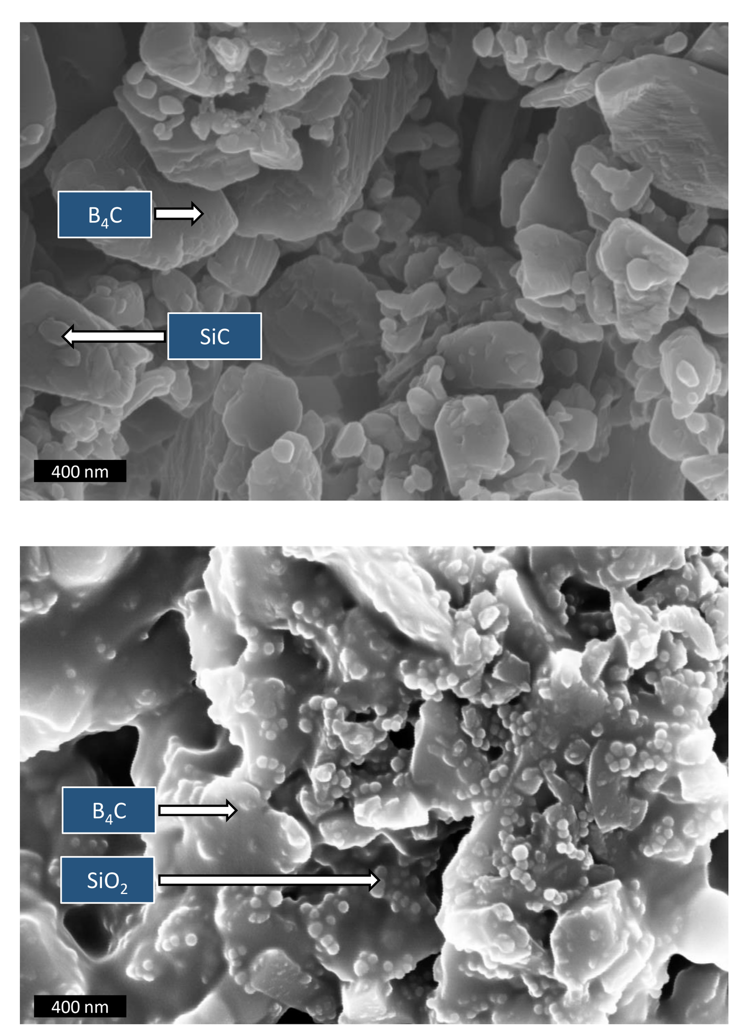

Figure 6: SEM micrographs showing the transformation of SiO_2 particles, dispersed in B_4C, to SiC .

Conclusion & Future Work

The work reported here has shown how SiO_2 nanoparticles can be reliably produced and characterised. In addition the transformation of SiO_2 to SiC can be seen to occur in a B_4C powder whilst maintaining its nano size. Future work will focus on the production of sintered B_4C-SiC composites and consider the effect of the inclusion of nano SiC on the amorphous breakdown of the armour.

Acknowledgements

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