Boron Carbide-Silicon Carbide nanocomposites for next generation armour

H.A.Payne, L.J.Vandeperre and F.Giuliani, Imperial College London, UK

Motivation

Modern warfare is developing rapidly; technology is becoming more advanced and the modern soldier requires more of it. With the increase in equipment there is an increase in weight which reduces mobility. Threats have also developed, in such environments greater protection can be required. Combining these two results in a need to produce lighter armour with a higher level of protection.

Materials

Boron Carbide (B_4C) has shown great potential for use in armours. It has a high hardness 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 a composite containing nano grains of B_4C and Silicon Carbide (SiC) can mitigate the polytype breakdown, whilst combining the low density of B_4C with the ballistic reliability of SiC.

Method

1 Production of SiC and B_4C nanopowders
Several options will be evaluated to develop a method for onshore nanopowder production.

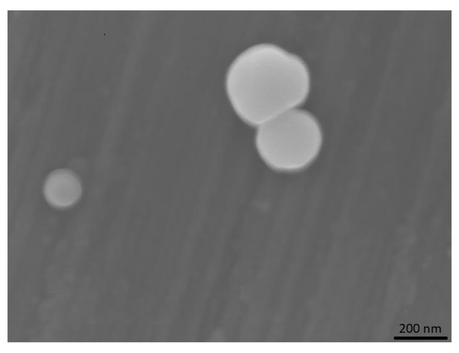


Figure 1: SEM micrograph of silica nanoparticles

2 Development of microstructure
Variation in compositions, sintering techniques and additives will lead to the development of a range of microstructures with potential to prevent amorphisation.

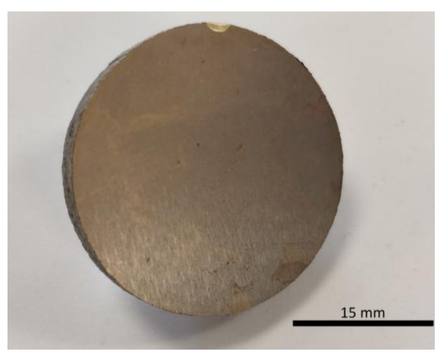


Figure 2: Image showing a B_4C sample coated in chromium before FIB milling

3 Understanding of amorphisation and ballistic performance
Nanoindentation and Ramen analysis will be used to quantify the extent of amorphisation in the new composites and evaluate suitability for ballistic armour.

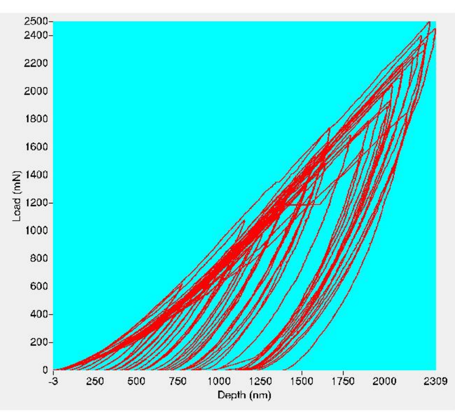
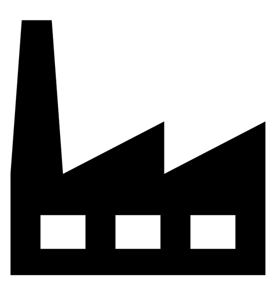


Figure 3: Load-depth hysteresis curves seen during micro indentation

4 Scale up of powder and composite production
Knowledge developed throughout the project will be used to design a production route for the desired composite on an industrial scale.



Results 1

Microemulsions
Particles were produced utilising a Water In Oil (W/O) microemulsion. Figure 4 shows a schematic of this system, whilst Equation 1 describes the overall reaction. Silica nanoparticles were produced; these undergo a carbothermal reaction to produce SiC powder.

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

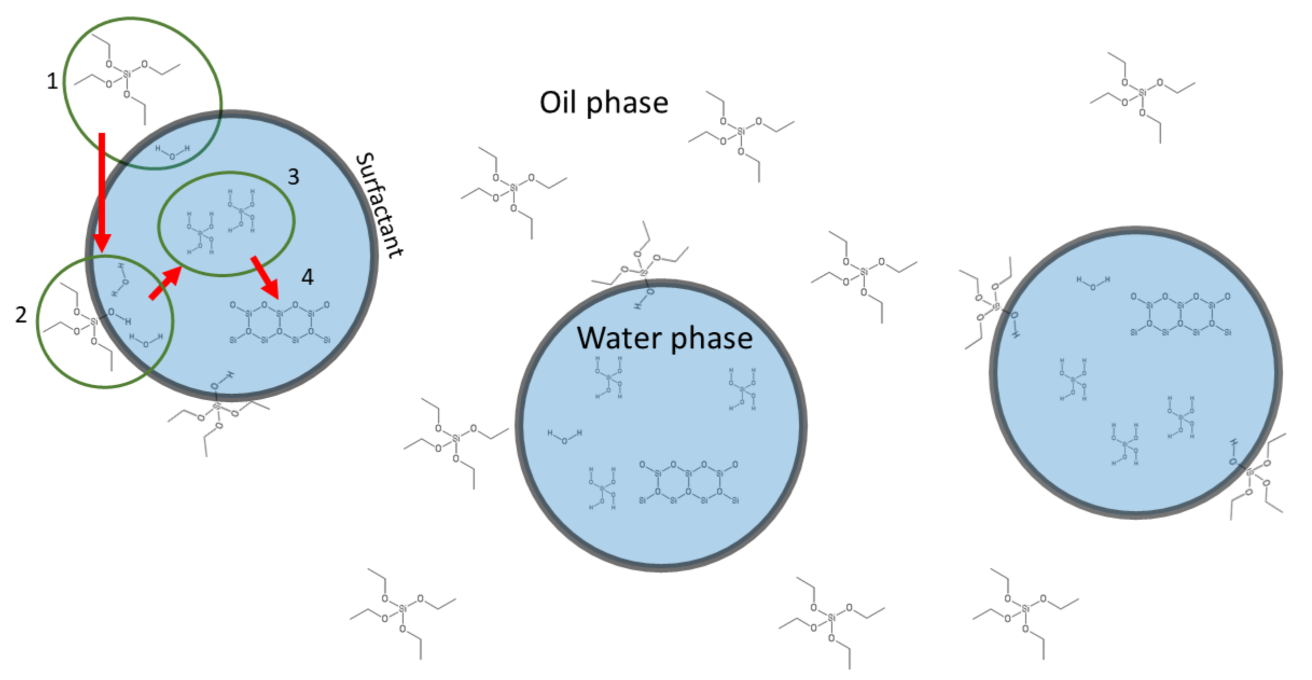


Figure 4: Diagram describing the W/O microemulsion and silica nanoparticle production reactions

Particle size and distribution
Particles have a spherical morphology with a normally distributed size about a mean of approximately 100 nm. This distribution is seen to change very little when the production is scaled up. Adding extra TEOS leads to limited change in size distribution and yield. This suggests that TEOS is in excess and more water must be added to increase yield. At the largest scale tested a yield of 31.5% was achieved.

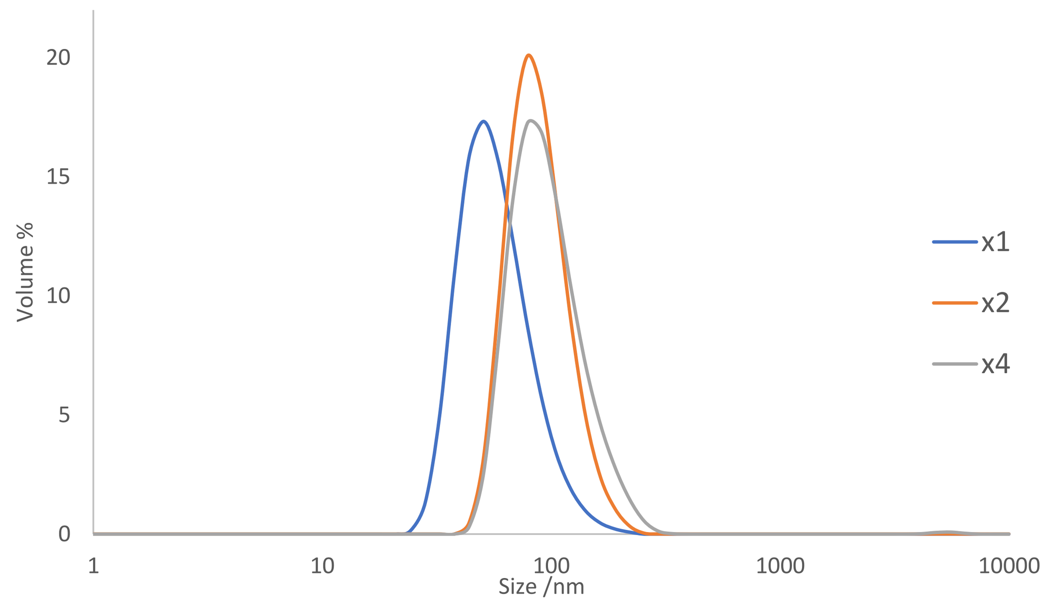


Figure 5: Graph showing the effect of scaling up the silica nanoparticle production by 2 and 4 times on size distribution of particles.
Volume % = Volume of Particles of size X / Total Volume of Particles in a sample.

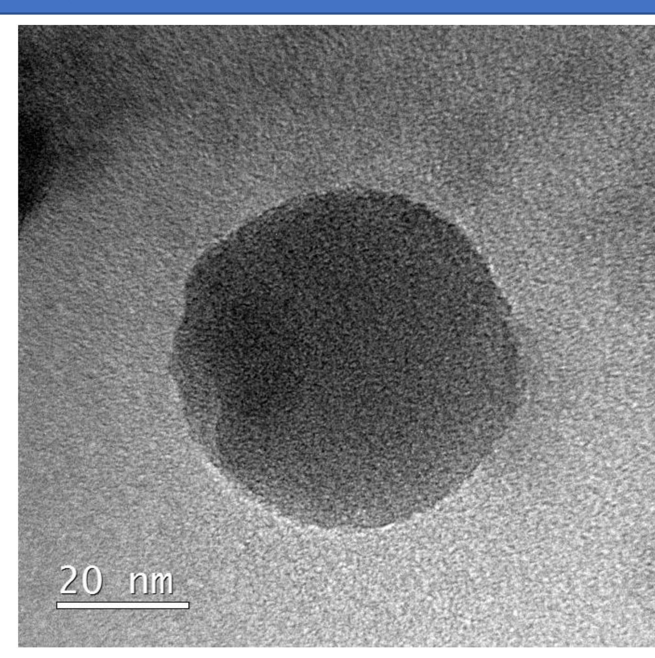


Figure 6: TEM micrograph showing a silica particle with a 50 nm radius

Future Work

Initial results are promising with production of a range of silica particle sizes with decrease in production time and increase in yield. Immediate future work will focus on production of SiC and B_4C powders to allow in-house composite production. These will follow the prescribed method above for the production of an appropriate nanocomposite ballistic armour.

Acknowledgements

This work is gratefully funded by the Defence Science Technology Laboratory and supported by Colin Roberson of NovaMat LTD