CHAPTER FIVE

5. Discussion of Results

This section gives detailed interpretation of the results obtained in this work. These results include the coating of the diamond, production of the diamond-SiC composites and the composites’ mechanical properties.

5.1 Coating of Diamond

Diamond was successfully coated with SiC and TiC using the chemical vapour deposition (CVD) process. This is because Si and Ti are well known to be good carbide forming materials. The coating of diamond with SiC was successful at 1300°C and with TiC at 750°C. At these temperatures, the microstructures of the coatings were uniform. At lower temperatures, SiC and TiC could not be formed on the diamond. Instead, elementary silicon and titanium carbo-nitrides were formed respectively. During the coating of diamond with SiC, the Si reacts with the ammonium chloride to form silicon tetrachloride. The produced silicon tetrachloride then ‘reacts’ with the C (diamond), thus transporting the Si to the diamond forming a SiC coating on the diamond particles. HCl and NH₃ are given off as gasses in the process. TiC coating on diamond also happens in a similar manner to that of SiC coating. Titanium tetrachloride is formed from the initial reaction between titanium and ammonium chloride. The titanium tetrachloride then ‘reacts’ with diamond and form a TiC coating on diamond. HCl and NH₃ are given off as gasses in the process as well.
5.2 Preform preparation and Infiltration

Small amounts of resin (≥ 5wt %) are needed to make the cold pressing of diamond particles possible, during the manufacturing of the preforms. No preforms could be prepared in the absence of the resin. The diamond particles are coated by the resin and the resin plastically deforms during pressing and glues the diamond particle together hence the binder effect.

Diamond is well wetted by liquid silicon at temperatures higher than 1450 °C [27] thus a pressureless infiltration is possible. The infiltration is affected by the formation of SiC surface layers on the diamond that can block the pore channels and reduce the infiltration depths. Infiltration is mainly governed by the combination between porosity and overall pore diameter. As could be seen in the uncoated diamond green compacts, the pore diameter remained nearly constant regardless of the increase in the resin content and decrease in the compaction pressure. The porosity increased with the reduction in compaction pressure and decreased with the increase in resin content. The reduction of porosity of the preforms with increases in resin content is due to the resin filling up the pores and the better compaction behaviour.

The increase in porosity of the preforms upon decreasing the green compaction pressure is the major factor in the improvement of the infiltration as observed. This is shown in Figure 5.1 below.
Fig. 5.1: A plot of infiltration heights obtained against porosity of the preforms for uncoated diamond preforms.

From Figure 5.1, it can be seen that an increase in the resin content caused an increase in the infiltration heights obtained, though it had caused a decrease in the porosity of the preforms (Fig. 4.7). The reduction of the overall porosity by deposition of the resin between the diamond particles is likely to reduce the depth of infiltration due to the possibility of blocking the pores. The volume increase during the reaction of diamond with liquid silicon is much larger than for the reaction of amorphous carbon or graphite with silicon [27], thus the reaction of the non-diamond carbon with silicon will result in the blocking of pores to a lesser extent. This phenomenon will reduce the influence of the increase in resin content on the reduction in porosity of the preforms.
Figure 5.2: A plot of infiltration heights obtained against the green density of the preforms for uncoated diamond preforms.

Figure 5.2 shows an increase in the infiltration depth with a decrease in the green density. If the regression line on the graph is extrapolated, it can be seen that a preform with a green density of 1.6 g/cm$^3$ will give rise to an infiltration depth of 4 mm.

When the material is coated with SiC, the coating retarded the reaction as expected and at the same time promoted infiltration. It was not possible to ascertain whether the pores increased due to the coating layer of the SiC because the porosimeter was not operational. The study of the interaction of diamond with molten silicon has shown that after the onset of the interaction, a silicon layer of 5-10 $\mu$m thickness is formed\(^{[26]}\) very quickly on the surface of the diamond particles so the presence of a SiC layer on the diamond particles...
retarded the fast reaction between diamond and silicon to form SiC thus hampering the ‘reaction chocking’ effect.

The phenomenon of reaction chocking is the one responsible for the difficulties in achieving full infiltration in fine-grained diamond preforms. If there would be no reaction taking place, the infiltration depth would be unlimited. If a reaction takes place, this would be followed by volume expansion during the formation of the products and this will result in rapid pore closure. Coating the diamond with SiC delayed the reaction between diamond and silicon, thus there was no rapid closure of the pores during product formation. This is evidenced by the increase in the infiltration depths of SiC-coated diamond preforms as compared to the uncoated ones, at the same green compaction pressure. The comparison of the infiltration depth achieved at different compaction pressures and green densities for SiC-coated and uncoated diamond preforms is shown in figures 5.3 and 5.4 below.
**Fig. 5.3:** A comparison of the infiltration depths obtained for the uncoated diamond and SiC-coated diamond against the green compaction pressure.

From the image analysis of the micrographs (Figures 4.14 and 4.23), the diamond content of the composites made from both SiC coated diamond and uncoated diamond is almost similar. Also there is no difference observed in the microstructures of both composites under SEM.
A study on the sintering of fine-grained diamond-SiC composites

Chapter 5: Discussion of Results

Fig. 5.4: A comparison of the infiltration depths obtained for the uncoated diamond and SiC-coated diamond against the green density.

5.2.1 Hardness and Wear Tests

The composites produced from fine grained diamond (grade 2) have a better wear resistance at low cutting speed (100m/min) than at high cutting speeds (400m/min). The wear resistance is comparable to that of Syndax at both cutting speeds. Since the composites tested are a lot cheaper to produce compared to the commercially available Syndax, these materials can be an excellent competitor of Syndax in wear applications.

From the studies of the wear scars, on the scared material, it can be deduced that the material wears firstly by abrasion of the softer phase (SiC) leaving the hard diamond phase exposed and protruding. The protruded diamond phase then get pulled out creating
some grooves in the process, thus further exposing the softer phase (binder phase). The binder phase will then get abraded in turn so further repeating the cycle and the cycle goes on.

Analysis of the hardness tests on the composites produced from both SiC-coated and uncoated diamond showed that an ultrahard material was produced. The breaking of the diamond indenter at a load of 35kg showed that the composites produced had a very high hardness value. Fracture toughness values could not be calculated as accurate measurements of the length of the indentation cracks was not possible.