

Chapter 8

Parametric Study

- Towards the Optimization of Polishing

8.1 Introduction

The ultimate aim of the research project is to establish a sound scientific methodology for the effective and efficient polishing of the thermally stable PCD composite surfaces, and optimize the processing conditions to obtain surface roughness requirements ($R_a \leq 60$ nm) for the cutting tool applications. To this end, in previous chapters, we have investigated the material removal mechanisms and developed a model to predict the temperature rise at the PCD surface during dynamical friction polishing (DFP). These studies would provide a guideline for the optimization process.

The research discussed in this chapter aims to control and optimize the polishing process to obtain the required surface finish efficiently and effectively. Since the two major constituents, diamond and SiC, have very different properties, eg., hardness, chemical reactivity, etc, the material removal rates for diamond and SiC are different

during DFP. In order to obtain the required surface finish both efficiently and economically, a combination of dynamic friction and mechanical process is used.

To achieve the aim, this chapter presents the optimization process by investigating the effects of DFP parameters on material removal rate and surface characteristics of polished specimens, which were carried out by optical microscopy, atomic force microscopy (AFM), a scanning electron microscope (SEM) and its attached energy dispersive X-ray (EDX) analysis. An attempt is then made to find out the proper polishing parameters to achieve the required high quality surface finish efficiently.

8.2. Experiment

8.2.1 PCD material

The PCD specimens used for the experiments were thermally stable diamond composite; its manufacture, properties, application and requirements were detailed in Chapter 5. Two types of the PCD specimens were used in the polishing experiments. Table 8.1 lists some properties of these two types of material. Type 1 PCD contains approximately 65% diamond particles of 6 μm in grain size (the rest are SiC and Si) with PCD surface roughness before polishing approximately 0.7 $\mu\text{m Ra}$. Type 2 PCD contains approximately 75% diamond particles of 25 μm in grain size with PCD roughness 1.6 $\mu\text{m Ra}$, which is the same material used in experiments discussed in Chapter 5. The diameter and thickness of these two types of specimens were 12.7 mm and 4 mm, respectively, weighing approximately 1.7 grams. The thermal conductivity of the specimen material was 300 W/m.K.

Table 8.1 Properties of PCD specimens used in polishing experiments

		Type 1	Type 2
Diamond percentage (%)		65	75
Grain size (μm)		6	25
Surface roughness	Ra (μm)	0.7	1.6
	Rmax (μm)	5	10
Size: diameter (mm) x thickness (mm)		12.7 x 4	12.7 x 4
Thermal conductivity (W/m.K)		300	300

8.2.2 Polishing machine and experiments

The dynamic friction polishing experiments were performed on an in-house designed and manufactured polishing machine, as detailed in Chapter 4. Polishing was conducted by pressing a PCD specimen at a predetermined pressure on to a rotating catalytic metal disk in dry atmosphere. Average sliding speeds in the range of 8 to 25 m/s were investigated. The specimen holder was rotated at 50 rpm to enable even polishing of the whole surface. The polishing pressure was varied by changing the load on the specimen. The effect of five different contact pressures 2.7, 3.1, 3.8, 5.0 and 7.4 MPa was investigated.

8.2.3 Characterization of specimen surface and material removal

The surface roughness was measured using a Surftest 402 and Surftest Analyzer (Mitutoyo). Surface topography including micro-cracks was examined by an optical microscope (Leica DM RXE). The surface structure and topography were also studied using SEM Philips 505; at the same time, EDX analysis was used to investigate the chemical composition at an interested area/spot. AFM was used to study the fine details and to determine the surface roughness of the polished PCD specimens. The AFM

studies were carried out on a PicoSPM multi-purpose scanning probe microscope, operating in AFM contact mode.

The amount of material removed was determined by measuring the weight and thickness of the PCD specimen before and after polishing. The specimen weights were measured by an electronic balance (Sartorius Basic^{plus} BP210D) with resolution 0.01 mg. The thickness of the specimens was measured by a micrometer, and by a comparator and slip gauges. The comparator allowed the thickness to be measured within $\pm 1.25 \mu\text{m}$.

8.3 Effect of DFP Parameters on Material Removal and Cracks Generated

8.3.1 Polishing time

The influence of polishing time on PCD material removal was first investigated for Type 1 specimens. When the sliding speed and polishing pressure were fixed at 25 m/s and 7.4 MPa, respectively, the effect of the polishing time on the PCD removal could be observed, as shown in Fig.8.1. The symbols represent the experimental results and the line represents the corresponding linear regression line.

It can be seen that the removal height (Fig.8.1 (a)) and weight (Fig.8.1 (b)) of the PCD specimen increases almost linearly with the polishing time. Thus, the removal rates of the PCD could be calculated as the height or weight of removed material divided by the polishing time, which gives a polishing rate of 26 $\mu\text{m}/\text{min}$ in height or 11 mg/min in weight. The surface roughness of the PCD specimen before polishing, 5 μm Rmax

(Table 8.1), is unlikely to have a significant effect on the material removal during polishing time at such a high polishing rate of 26 $\mu\text{m}/\text{min}$.

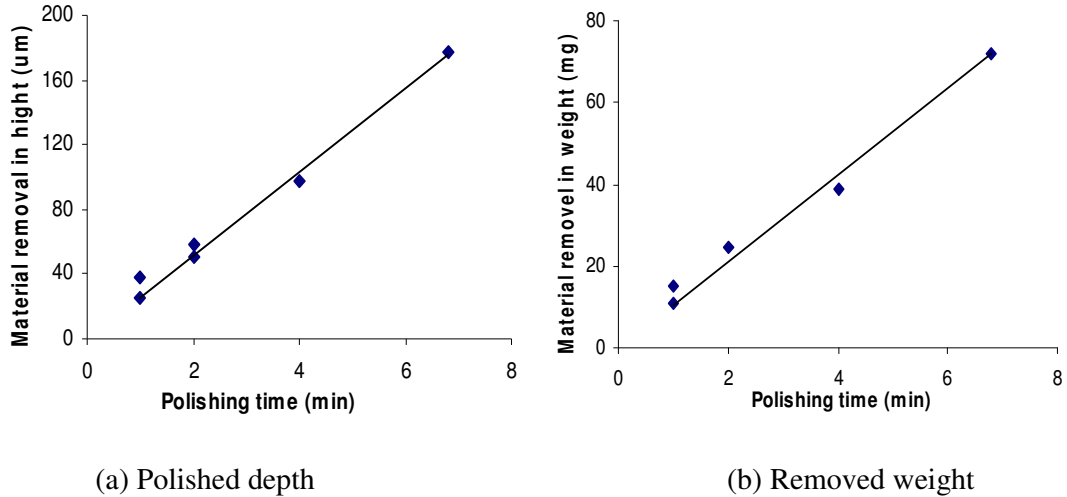
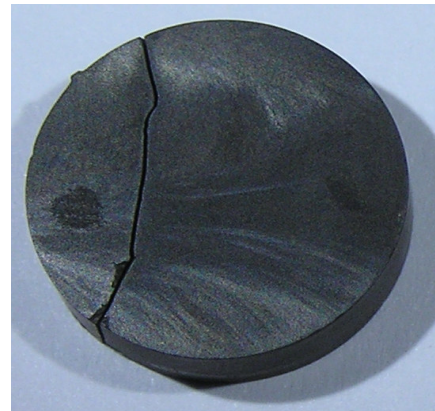


Fig.8.1 Effect of polishing time on PCD removal for Type 1 specimens

Compared to the traditional mechanical abrasive method with a polishing rate of the order of 10 nm/h [Sudarshan, 1995], the increase in polishing rate achieved in the present tests is greater by thousands of times. However, under these polishing conditions, cracks were easily generated on the polished PCD surfaces, and sometimes PCD compacts were fractured. Figure 8.2 shows some typical serious failures of Type 1 PCD specimens after DFP. Therefore, the polishing should be conducted at lower sliding speed/pressure to avoid cracking/fracture.



(a) Cracks



(b) fracture

Fig.8.2 Failure of polished Type 1 PCD specimen

The influence of polishing time on PCD material removal was also studied at polishing pressure 3.1 MPa to avoid cracking/fracture and at sliding speed 25 m/s for sufficient material removal. The PCD removal as a function of the polishing time is depicted in Fig.8.3 for both types of PCD specimens.

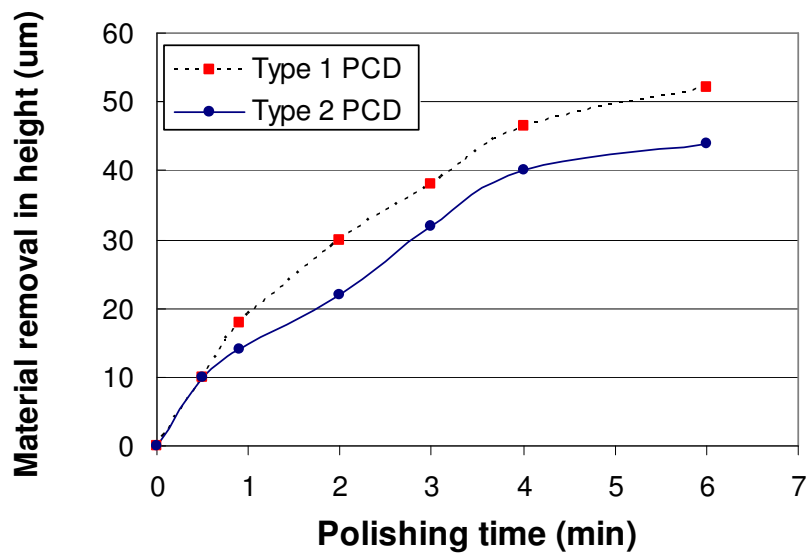


Fig.8.3 Effect of polishing time on PCD removal

From Fig.8.3, it is clear that the material removal is not directly proportional to polishing time, as the removed material appears to tail off, most significantly after four minutes. When polishing time is more than one minute, the material removal of Type 1 PCD is higher than that of Type 2 PCD. This lower material removal of Type 2 specimens may be due to the bigger grain size in these PCD compacts. As we know from Chapters 5-7, the material removal mechanism during DFP is chemical reactions and phase transformation. Diamond with small particle size has more surface area and surface defects, and chemical reaction starts at the surface defects [Lee *et al.*, 2004]. Also the bigger grain size of SiC is harder to remove.

However, when polishing time is half a minute, the material removal of the two types of PCD is the same at 10 μm . The likely reason is that the surface roughness R_{max} (value of peak to valley) of Type 1 and Type 2 PCD is 5 and 10 μm , respectively. In this half minute, the removed material of Type 2 PCD is mainly from the peak of the rough surface, contact area of which is smaller.

8.3.2 Pressure

The pressure dependency of the removal rate was investigated by changing the pressure on the specimens while the polishing speed was kept constant at 25 m/s or 16m/s, and polishing time at 2 minutes for Type 1 specimens and 3 minutes for Type 2 for sufficient material removal. The levels of the polishing pressure used were 2.7, 3.1, 3.8, 5 and 7.4 MPa. Figure 8.4 shows the effect of polishing pressure on the material removal rate.

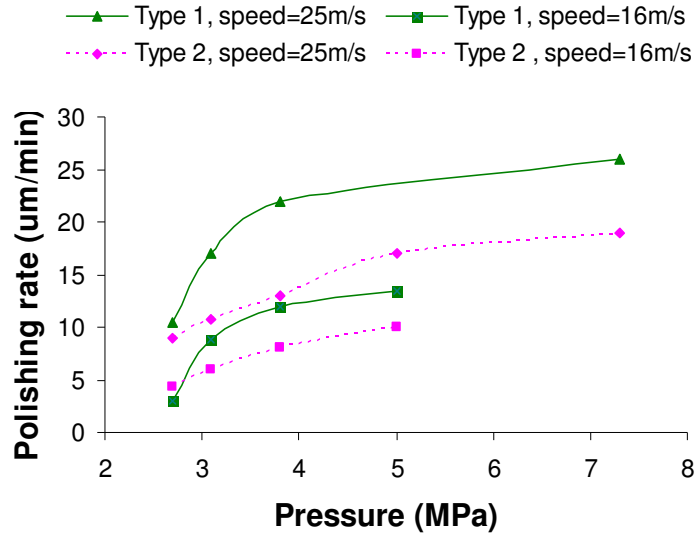


Fig.8.4 Effect of pressure on polishing rate

For Type 1 specimens, the PCD removal rate increases with the increasing pressure up to about 4 MPa. Further increase in pressure does not result in a significant increase in removal rate. The relation between removal rate and pressure seems to follow a power law. It was noticed that at polishing speed 25 m/s, no cracks were found when the pressure was 2.7 or 3.1 MPa. However, when the pressure was increased to 3.8 MPa, cracks began to appear. When pressure was further increased to 7.4 MPa, cracking or fracture of PCD occurred.

It was noticed that when sliding speed was reduced to 16 m/s and the pressure was kept at 7.4 MPa, more polishing disk material adhered to the PCD surface and polishing could not successfully continue. Additionally, the specimens were found fractured. At this speed, no crack was found when pressure was 2.7, 3.1 or 3.8 MPa. But cracks appeared when pressure was increased to 5 MPa. Thus, these results show that polishing pressure must be reduced for effective polishing.

For Type 2 PCD specimens, the polishing rate increases slowly with the increasing pressure, and it further slows down after 5 MPa. The relation between removal rate and pressure also seems to follow a power law, but at a lower power. At polishing speed of 25 m/s, no cracks were found when the pressure was 2.7 or 3.1 MPa. But cracking was observed when the pressure was above 3.8 MPa. At sliding speed of 16m/s, cracks only appeared at pressure 5 MPa. No cracks were found at other tested pressures.

The pressure on the specimens increases the real contact area at the polishing disk and PCD interface. Since the Type 1 PCD specimens are made of smaller grain size powder than Type 2, the real contact area may increase faster than that of Type 2 specimens as the pressure increases. Thus the Type 1 PCD removal rate increases faster with the increasing pressure up to about 4 MPa.

On the other hand, the surface roughness R_{max} of Type 1 PCD is about 5 μm , which is much less than the Type 2 specimen with R_{max} 10 μm ; the contact area is harder to increase further when the pressure is up to 4 MPa. It is expected that further increase in pressure does not result in a significant increase in removal rate, instead the higher pressure will cause cracking and fracture.

From Fig.8.4, it can be seen that for a fixed sliding speed, the relation between removal rate and pressure seems to follow a power law. This relation is similar to the relation between the interface temperature rise and pressure which also seems to follow a power law (Fig.6.4). It might indicate that the removal rate is a function of temperature through polishing parameters.

8.3.3 Sliding speed

The effect of the sliding speed on the removal rate was investigated by varying the sliding speed while the pressure was kept constant for both types of PCD specimens. Figure 8.5 shows the fitted lines for Type 1 specimens for the experimental results, when polishing was conducted on a sliding speed varying between 8-25 m/s while the pressure was kept a constant at 2.7, 3.1 or 3.8 MPa. The polishing time was maintained constant at two minutes for all the conditions except at pressure 2.7 MPa and speed 12-20 m/s where a longer time of three minutes was necessary to obtain a measurable material removal.

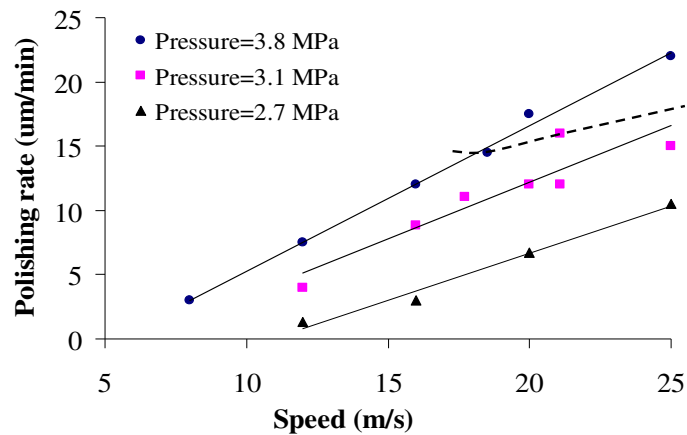


Fig.8.5 Effect of sliding speed on polishing rate for Type 1 PCD

For Type 1 specimens, when the speed was low (8 m/s), PCD could not be polished at all at pressure = 2.7 MPa. The PCD could only be partially polished at pressure = 3.1 MPa. At a higher sliding speed, as shown in Fig.8.5, the polishing rate increased almost linearly with the increase in sliding speed. An even higher polishing rate can be expected by further increasing the speed. At a given polishing speed, a higher pressure also resulted in a higher polishing rate. However, cracking occurred in PCD under the

following polishing conditions, as shown above the dotted line in Fig.8.5: pressure = 3.8 MPa, and sliding speed = 18.5 to 25 m/s; pressure = 3.1 MPa and sliding speed = 21 m/s.

For Type 2 specimens, the effect of the sliding speed on the removal rate was studied by varying the sliding speed between 8-25 m/s while the pressure was kept a constant at 2.7, 3.1 3.8 or 5 MPa. The polishing time was maintained constant at three minutes. The fitted lines for the experimental results are given in Fig.8.6. It is noticed that when the speed was lower than 10 m/s, PCD could only be partially polished or not polished at all. At a higher sliding speed (>12 m/s), the polishing rate increased almost linearly with the increase in sliding speed. At a given polishing speed, a higher pressure also resulted in a higher polishing rate. However, cracking occurred in PCD under the following polishing conditions, as shown above the dotted line in Fig.8.6: pressure = 5 MPa, and sliding speed = 16 to 25 m/s; pressure = 3.8 MPa, and sliding speed = 20 to 25 m/s; pressure = 3.1 MPa and sliding speed = 24 m/s.

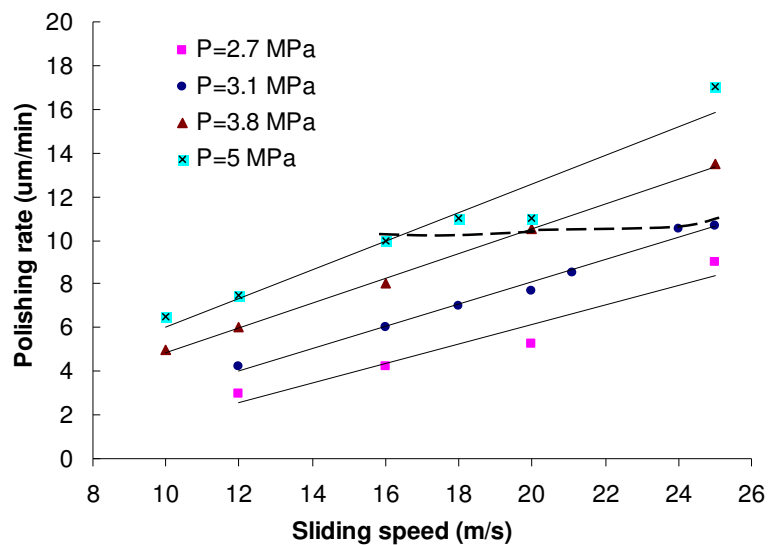


Fig.8.6 Effect of sliding speed on polishing rate for Type 2 PCD

These results show that an increase in sliding speed will increase the material removal rate and thus reduce polishing time. However, cracks can be generated under severe conditions (e.g., very high pressure/speed).

Figure 8.7 compares the polishing rates for the two types of specimens. Dotted lines represent the fitted linear regression lines for Type 1 specimens, while solid lines represent Type 2 specimens. Generally, at an identical polishing speed and pressure, the removal rate of Type 1 specimens is higher than that of Type 2. However, at low speed and pressure, e.g., at pressure=2.7 MPa, speed=12, 16 m/s, Type 1 specimens have lower material removal rate than Type 2. The reason for the former is that Type 1 PCD is compressed with smaller size grain and was removed easier. The reason for the later is that at such a low removal rate of 2-4 $\mu\text{m}/\text{min}$, the small amount of material removed is from the peaks of the rough specimen which have a smaller contact area, and the height of peak in Type 2 (10 μm R_{max}) is higher than that of Type 1 (5 μm R_{max}).

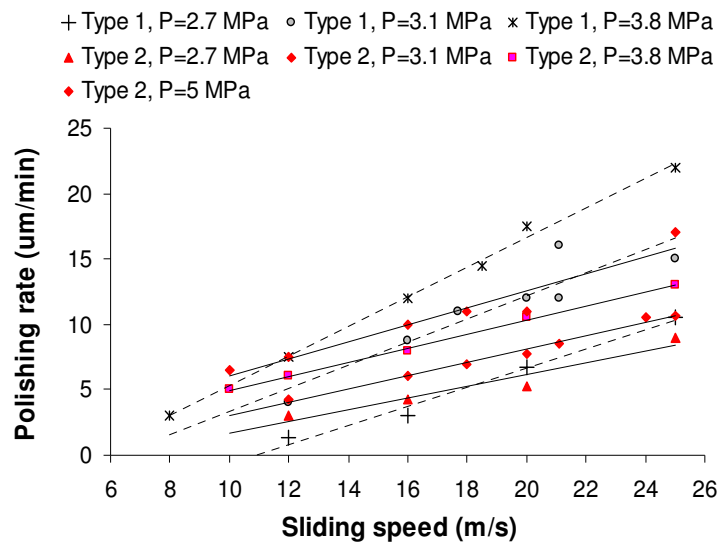


Fig.8.7 The effect of sliding speed on polishing rate for both types of PCD

The results presented in Fig.8.5-8.7 are based on limited experiments, i.e., one test for each condition. This may represent a degree of non-repeatability. As a result it is not possible to produce error bars. Additionally, sufficient time was allowed (at least four hours) in between the tests. We have found that, if we conducted three consecutive tests under identical conditions (with only a few minutes in between), material removal rate would be different for the second and third tests. This polishing rate dependency on test sequence is discussed in greater detail in the next section.

8.3.4 Other factors –test sequence

It was noticed that if more than two consecutive tests under identical conditions were conducted one after another within a very short time interval, e.g., a few minutes, the material removal rate would vary in the subsequent tests. Figure 8.8 shows the material removal rate when five consecutive polishing tests were carried out one after another at an identical pressure and speed for Type 2 specimens. The first three specimens are the same, as shown in Table 8.1, with surface roughness of about 1.6 $\mu\text{m Ra}$; but the last two specimens were polished before with roughness about 0.2 $\mu\text{m Ra}$. The material removal rate of the second polishing increases 21.5% to 13 $\mu\text{m/min}$ from the first polishing at a rate of 10.7 $\mu\text{m/min}$, while the removal rate from the second to the third increases 7.7% to 14 $\mu\text{m/min}$. The fourth polishing rate reduced 30% from the third to 9.7 $\mu\text{m/min}$, possibly due to the lower surface roughness.

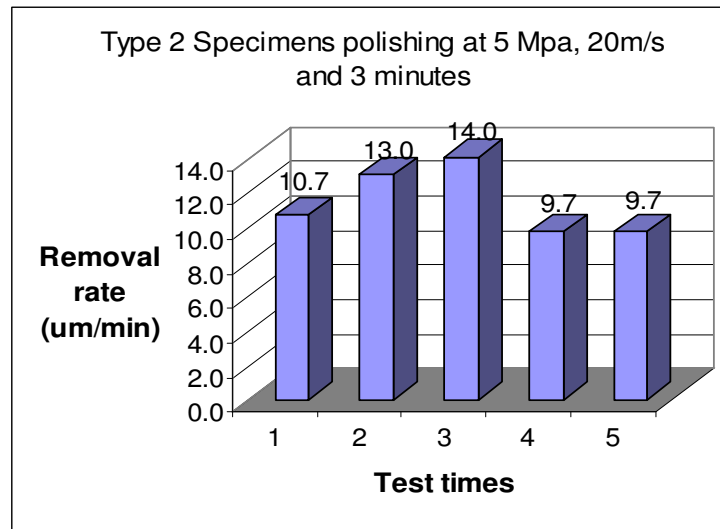


Fig. 8.8 Material removal rate versus test sequence

More results from the test sequence, as shown in Table 8.2, demonstrate that the material removal rate for second time polishing is higher than for the first time under identical conditions. Until now, we have not found any results that demonstrate that, under identical conditions, the polishing rate in the first test is higher than that in the second or subsequent test.

Table 8.2 More results from sequence tests

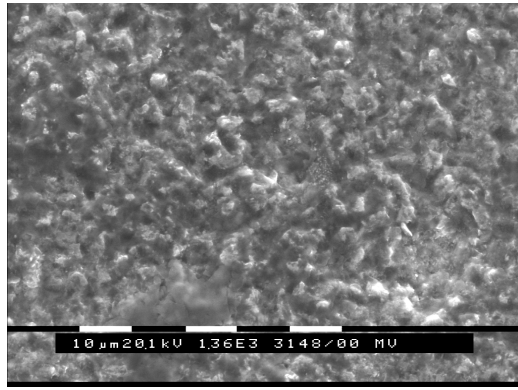
Specimen	Polishing condition (pressure, speed)	First time Polishing rate (µm/min)	Second time polishing rate (µm/min)	Difference (increase)
Type 2	5 Mpa, 25 m/s	17	21	23.5%
Type 2	3.8MPa, 20 m/s	11	14	27.2%
Type 2	3.1MPa, 16 m/s	6	7.3	22.2%
Type 1	3.8MPa, 18.5 m/s	14.5	17.5	20.7%
Type 1	3.8MPa, 16 m/s	12	16	33.3%

The mechanism responsible for such a rate change is not yet clear. Further research needs to be carried out to understand whether it is due to the rise in polishing temperature and/or some unknown changes of conditions at the specimen-disk interface.

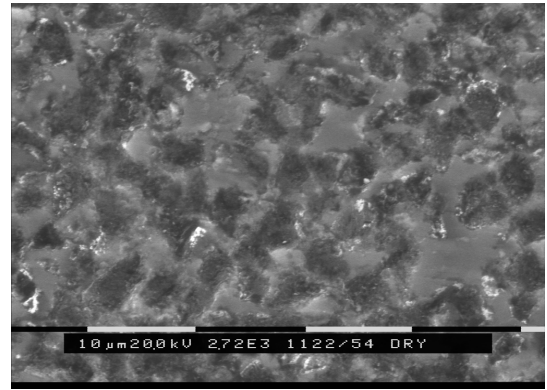
8.4 Surface Topography

Figure 8.9 shows the SEM images of the surface topography of a typical Type 1 PCD specimen before and after dynamic friction polishing. Before polishing, the surface was rough (Fig.8.9 (a)) and could not be seen clearly under light microscopy due to its short depth of field. The surface roughness of the specimen was approximately 0.7 μm Ra and 5 μm Rmax.

After polishing, the surface of the PCD specimen improved, the roughness Ra value of these specimens was measured to be in the range of 0.1-0.2 μm , which had decreased markedly. However, under high magnification on SEM (2720 times, Fig.8.9 (b)), it was found that the bright grains were higher than the dark “cavities”. The polished surface did not reach the target value 0.06 μm Ra even with increasing the polishing time or changing the polishing parameters.



(a) Before polishing

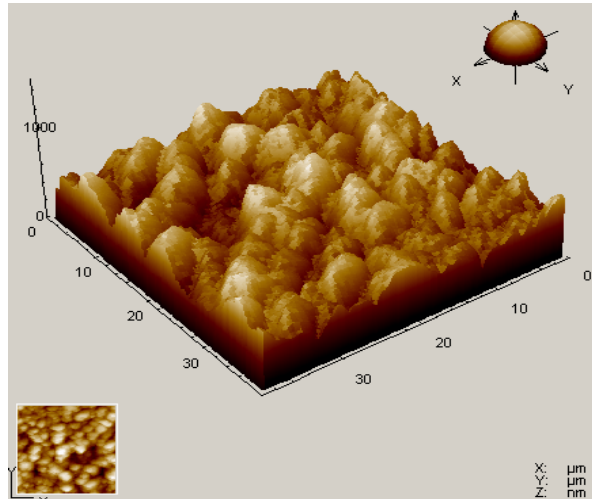


(b) After polishing at 3.1MPa and 20 m/s

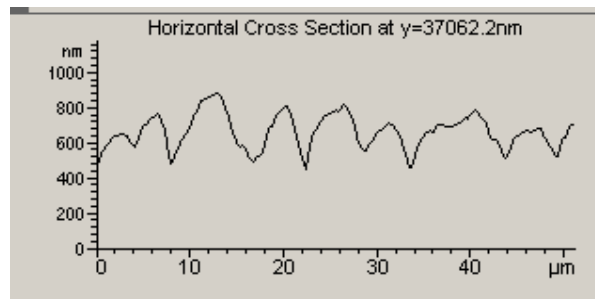
Fig.8.9 SEM image of Type 1 PCD specimen surface before and after polishing

The SEM images of the surface topography of a typical Type 2 PCD specimen before and after DFP were depicted in Fig. 5.1, in Chapter 5. Before polishing (Fig.5.1 (a)), surface roughness of the specimen was approximately 1.6 μm Ra and 10 μm Rmax. After polishing (Fig.5.1 (a)), the surface roughness decreased nearly an order from 1.6 μm to about 0.2 μm Ra. It was also found that the bright grains were higher than the dark “cavities”.

The fine details of the polished surface could be observed more clearly by AFM. Figure 8.10 shows the AFM image and the surface roughness profile for Type 1 PCD. It can be seen that the surface after DFP was not flat but has peaks and valleys (Fig. 8.10 (a)), but without scratching marks, indicating that the material was not removed by mechanical abrasion, but by chemical reactions, as discussed in Chapters 5 and 7. The asperity peaks were sharp (Fig. 8.10 (a)), and the Rmax value was about 500 nm (0.5 μm) (Fig. 8.10 (b)) which had reduced markedly from 5 μm Rmax before polishing.



(a) AFM image

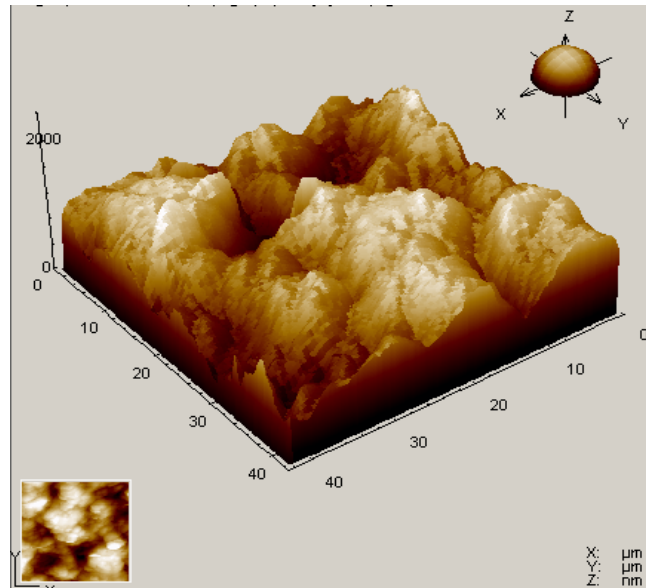


(b) Surface roughness profile

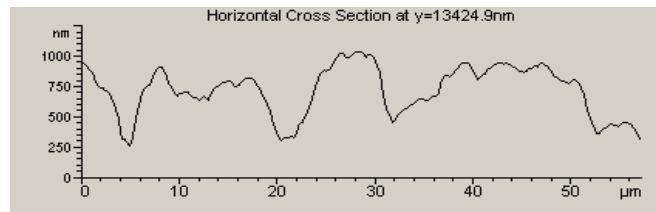
Fig.8.10 Polished Type 1 PCD specimen through AFM

For Type 2 specimens, the fine details of the polished surface studied by AFM are shown in Fig. 8.11. The surface after DFP also has peaks and valleys (Fig. 8.11 (a)), and without scratching marks, again indicating that the material was removed by chemical reactions. The asperity peaks were sharp, but not as sharp as those of Type 1 (Fig. 8.11 (a)). The peaks are larger than those in Type 1 specimens. The likely reason is that the Type 1 specimens are made of diamond powder with smaller grain size, and the chemical reaction starts at the surface defects and grain boundary.

The surface profile of the polished specimens obtained from AFM (Fig. 8.11 (b)) shows that the R_{max} value of Type 2 PCD was approximately 700 nm (0.7 μm), which had reduced significantly from a 10 μm R_{max} value before polishing.



(a) AFM image



(b) Surface roughness profile

Fig.8.11 Polished Type 2 PCD specimen through AFM

Such a surface topography could be generated by different material removal rates of diamond and SiC during polishing. To confirm this, EDX in SEM was applied to find out the composition at the peak and valley areas. Fig.8.12 shows the typical components on a polished Type 1 PCD surface obtained using EDX analysis under high magnification of SEM. On the whole area analysed, slightly larger quantities of silicon

than that of carbon were detected on the surface (Fig.8.12 (a)). On the dark cavity spots, which were under the surface, a medium quantity of silicon and a large amount of carbon were found (Fig.8.12 (b)). At the bright peak spots, a large quantity of silicon and small amount of carbon were detected (Fig.8.12 (c)). These show that there are more SiC on the peak areas and more diamond carbon on the valley areas.

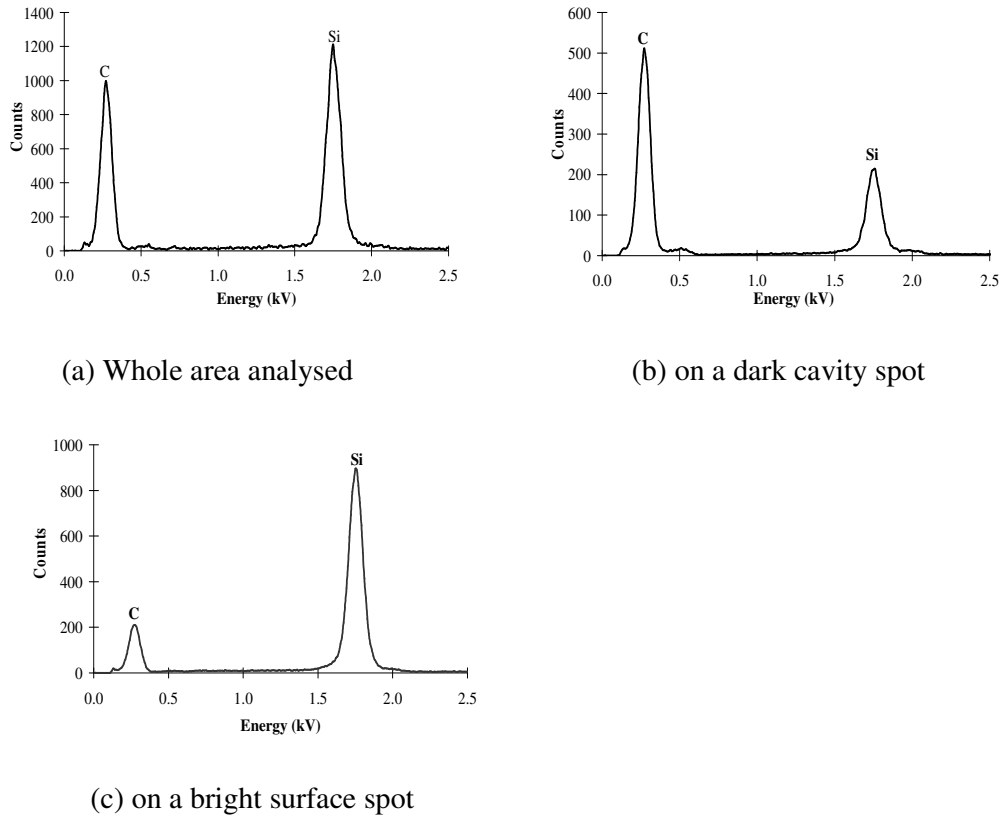
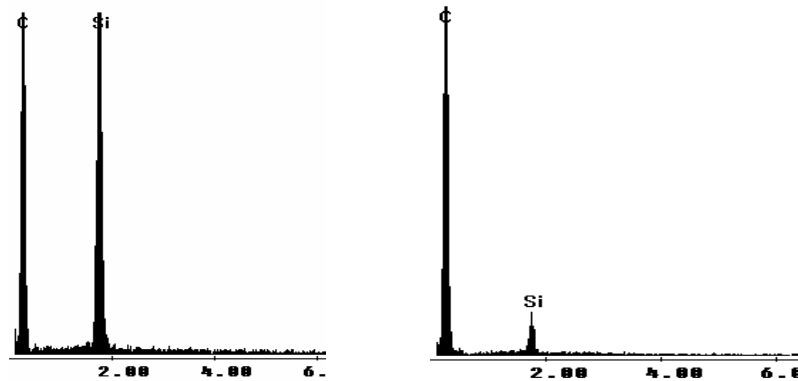


Fig. 8.12 EDX analysis of DFP polished Type 1 PCD surface

For Type 2 PCD, similar results obtained from EDX analysis are shown in Fig.8.13. Over the whole area analysed, similar quantities of carbon and silicon were detected on the surface (Fig.8.13 (a)). On the dark cavity spots, a small quantity of silicon and a large amount of carbon were found (Fig.8.13 (b)). At the bright peak spots, a large quantity of silicon and medium carbon were detected (Fig.8.13 (c)).

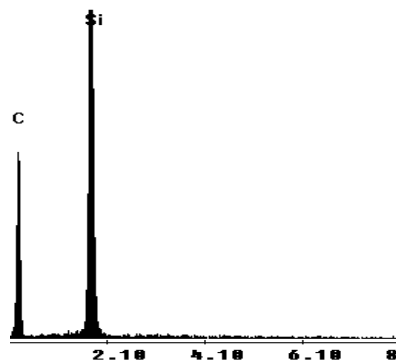
Comparing Fig.8.12 and 13, the trend in changing the percentage of carbon and silicon is the same; the only difference is that the relative percentage of carbon in Type 2 PCD (Fig. 8.13) is slightly higher than that in Type 1 PCD (Fig.8.12). That is because the percentage of diamond in Type 2 PCD at 75% is higher than that in Type 1 at 65%.

These results indicate that the material removal rate of diamond is faster than that of SiC during polishing. Therefore, further processing is required to reduce the surface roughness and improve the PCD surface quality.



(a) Whole area analysed

(b) on a dark cavity spot



(c) on a bright surface spot

Fig.8.13 EDX analysis of polished Type 2 PCD surface

8.5 Optimization of Polishing for Required Surface Finish

8.5.1 Polishing parameters for crack free surface

A higher polishing pressure and sliding speed resulted in higher polishing rate, but did not necessarily result in a good quality polished surface. Increasing the polishing time increased the amount of material removed, but it could not reduce the surface roughness to the target value of 0.06 $\mu\text{m Ra}$. The best Ra value achieved was 0.1 μm . On the other hand, cracking/fracture of PCD could occur after polishing at high pressure and sliding speed.

The brittleness of diamond under high pressure may contribute to the cracks and fracture. In addition, the cracks produced during DFP might be explained by its material removal mechanism. From previous Chapters 5-7, it was found that during dynamic friction polishing, the diamond on the PCD surface had transformed to amorphous non-diamond carbon, which was then removed mechanically/chemically. The temperature rise is seen to increase with increasing pressure and sliding speed. As discussed in Chapter 7, the rate of transformation is a function of temperature.

During DFP, the metal from the polishing disk adhered to the PCD surface. The elevated temperature and contact with the catalytic metal would accelerate the transformation of diamond to non-diamond carbon. The high pressure and speed would cause not only the interface temperature but also the subsurface PCD temperature to rise above the critical point of fast transformation of diamond to non-diamond, and transform it to non-diamond carbon. Since the densities of the non-diamond carbon

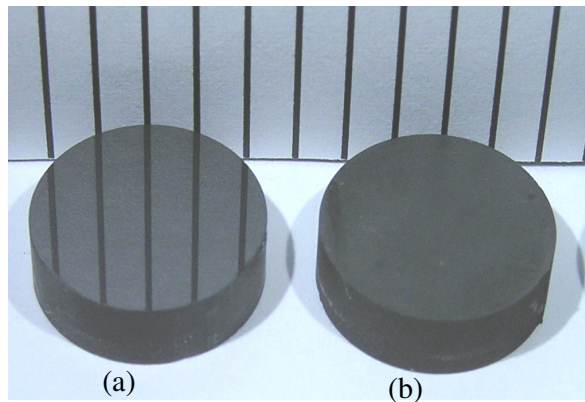
varied in the range of 1.8-2.5 g/cm³, as discussed in section 5.6.4, Chapter 5, they were much less than the density of diamond (3.5 g/cm³). The marked increase in volume due to the transformation would significantly increase the stress in the PCD and then easily generate cracks on the PCD.

Using DFP, in order to obtain a crack free PCD surface, lower pressure and higher sliding speeds seem suitable. The pressure/speed combinations for DFP that were tested to determine the effective polishing parameters for Type 1 specimens were shown in Fig. 8.5. Among the conditions tested, it was found that the most appropriate ones are: (1) pressure = 2.7 MPa, sliding speed = 20 to 25 m/s; (2) pressure = 3.1 MPa, sliding speed = 16 to 25 m/s; and (3) pressure = 3.8 MPa, sliding speed = 16 m/s. The dotted line in the figure indicates roughly the boundary of the safe region below which polishing can be carried out without cracking.

Similarly, Figure 8.6 gave the pressure/speed combinations that were tested to determine the effective ones for Type 2 specimens. The dotted line in the figure also indicates roughly the boundary of the safe region below which polishing can be carried out without cracking. Among the conditions tested, the most appropriate parameters are: (1) pressure = 2.7 MPa, sliding speed = 25 m/s; (2) pressure = 3.1 MPa, sliding speed = 18 to 25 m/s; (3) pressure = 3.8 MPa, sliding speed = 16 m/s; and (4) pressure = 5 MPa, sliding speed = 12 m/s.

8.5.2 Optical surface finish

During DFP, cracks on the PCD surfaces could be controlled by selecting the appropriate polishing parameters, and the surface roughness was reduced to the range of 0.1 to 0.2 $\mu\text{m Ra}$. However, it could not be improved any further because the material removal rate of diamond is faster than that of SiC.

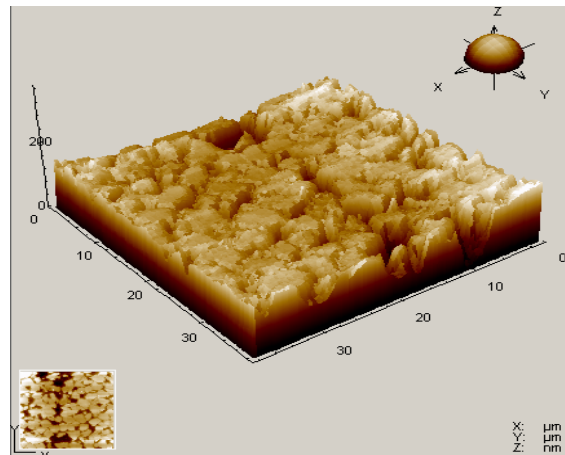


(a) After polishing with mirror finish (b) before polishing

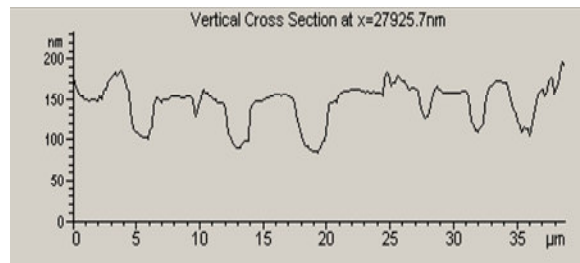
Fig.8.14 PCD surface

Thus, further mechanical abrasive polishing was applied to remove the protruding SiC and further polish the PCD to generate a required optical surface finish (Fig.8.14 (a)). The abrasive polishing time required depends on the accuracy of relocating the specimen from the DFP machine to the abrasive polishing machine. In the present work, the specimen relocation was done manually and thus introduced considerable tilting of the specimen. Because of this, the polishing of the whole surface of the relocated specimen required about 15 minutes. If an automatic relocation mechanism is attached, the time will be very much reduced. For comparison, a PCD specimen before polishing is shown in Fig.8.14 (b). The roughness of the polished surface (Fig.8.14 (a)) was 0.05 μm (50 nm) Ra. The optical mirror surfaces could be achieved in 17 and 18 minutes for Type 1 and Type 2 PCD specimens, respectively.

The final polished surface were also studied by AFM and SEM. Figures 8.15 and 8.16 show the surfaces after DFP and a sequent mechanical abrasive polishing through AFM for Type 1 and Type 2 PCD, respectively. These images show that the top surfaces have become flat, as in Fig.8.15 (a) and Fig.8.16 (a), and scratching lines due to mechanical polishing can be observed in the high resolution image (left image in Fig.8.16 (a)). The Rmax value was approximately 120 nm for both types of PCD, as shown in Fig.8.15 (b) and Fig.8.16 (b).

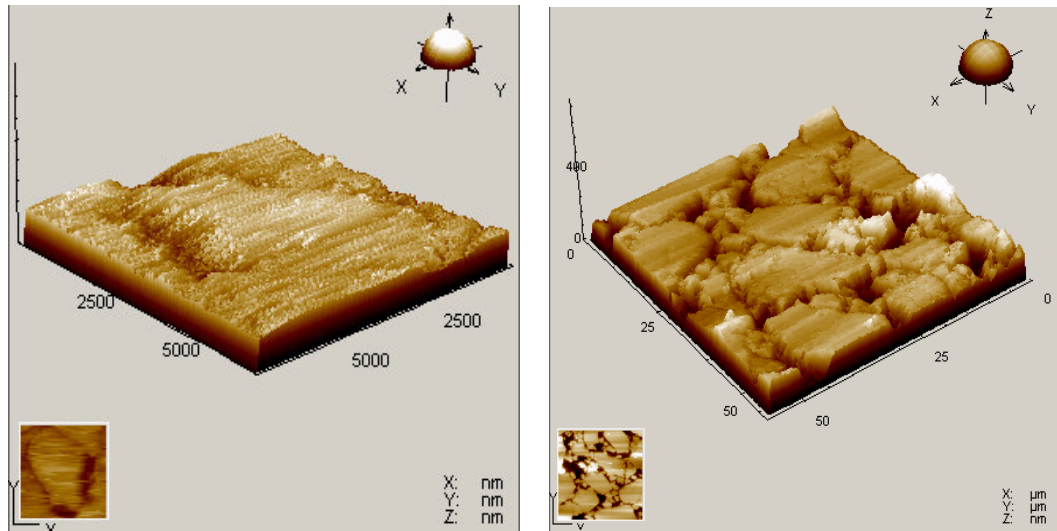


(a) AFM image

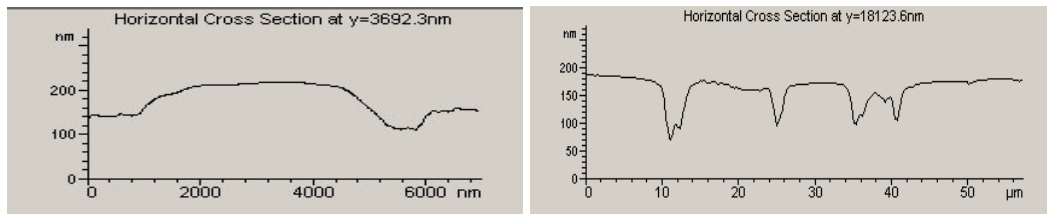


(b) Surface roughness profile

Fig. 8.15 Type 1 PCD surface after DFP and a sequent mechanical abrasive polishing



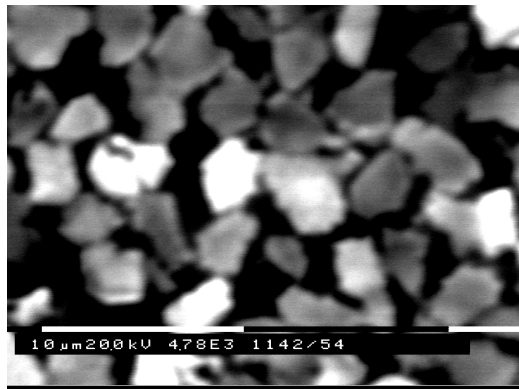
(a) AFM image



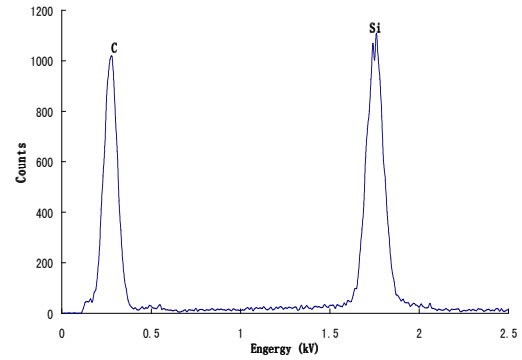
(b) Surface roughness profile

Fig. 8.16 Type 1 PCD surface after DFP and a sequent mechanical abrasive polishing

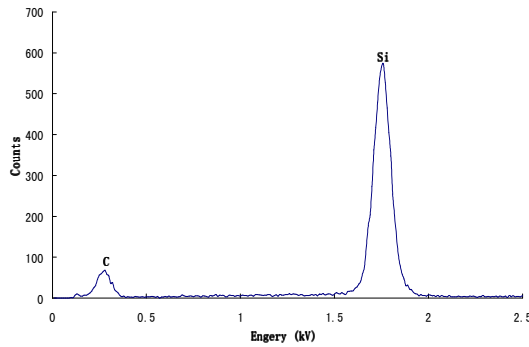
Figure 8.17 shows the SEM image and components on the surface obtained using EDX analysis in high magnification of SEM for Type 1 PCD. The top surfaces have become flat, as shown in Fig.8.17 (a). Over the whole surface area analysed, almost the same quantity of carbon and silicon were detected (Fig.8.17 (b)), which is similar to that after only DFP. On a dark cavity spot, which was slightly under the flat surface, a little carbon and a large amount of silicon were found (Fig.17(c)). At white bright spot of the flat surface, a large quantity of carbon and medium silicon were detected (Fig.17 (d)). These results indicate that the protruding SiC has been removed by the mechanical polishing and the material removal rate of SiC was faster than that of diamond during mechanical polishing.



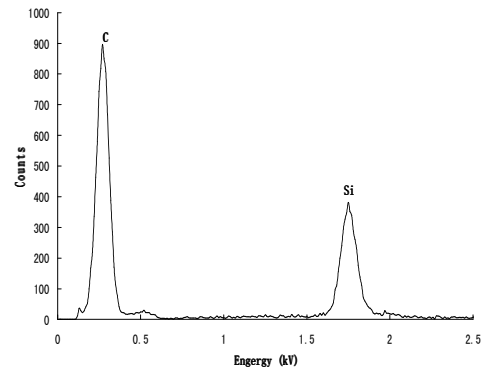
(a) SEM image



(b) whole area analysed



(c) on dark cavity spot



(d) on bright peak spot

Fig. 8.17 SEM and its attached EDX analysis of polished Type 1 PCD surface

8.6 Conclusion

The work described in this chapter investigated the optimum DFP parameters based on the material removal rate, surface characteristics and cracking /fracture of PCD. The final aim was to achieve the surface roughness of industrial PCD cutting tools, 0.06 μm Ra. It was found that combining dynamic friction polishing and mechanical abrasive polishing, a very high polishing rate and good quality surface can be obtained. The final surface roughness can be reduced to 50 nm Ra for both types of PCD specimens

considered from pre-polishing value of 0.7 or 1.5 $\mu\text{m Ra}$. The polishing time required is 18 minutes, a ten fold reduction compared with the mechanical abrasive polishing currently used in industry.