Tribo-chemical Smoothing of Diamond Film

Ken'ichiro HORIO, Makoto HYOHDOH, Toshio KASAI
Mechanical Engineering Department, Saitama University
255 Shimo-ohkubo, Urawa, 3388570, JAPAN

1. Introduction

For last twenty years much effort for depositing diamond film has being conducted. Chemical Vapor Deposition (CVD) technique that uses combination of carbon contented gas (for example methane, ethane and so on) and hydrogen has developed successfully. The diamond film is good material from the point of high hardness, high heat conductivity, high electrical insulation, chemical resisting, high transparency and high index of refraction. So the film is expected to apply (1)coating where wear resistance is needed, (2)a new material candidate of semiconductors for severe environment, (3)optical window material for severe environment for example ultraviolet or X-ray irradiation, or other fields.

In order to apply the diamond film for those particular areas, it can be necessary to smooth the surface of the deposited diamond. Generally speaking, smoothing is conducted by removing only the peak area of the surface. If you intend to wear the diamond peak mechanically, strong friction is needed. The strong friction may cause exfoliation (peeling off) because bond strength between the diamond and the substrate is not so high. Thus our developing polishing technique for tools for diamond turning may be hard to be applied.

As the CVD diamond film is an accumulation of minute crystal growth, the film is polycrystalline and has small peak and valley. Another problem caused by the polycrystalline is that the wear rate by mechanical friction along the different crystal axis varies very much at the diamond, which makes hard to remove all the peaks uniformly. In this study our object is to smooth rather thin, a few micrometer, film for optical or semi-conductor application. Therefore to avoid exfoliation (peeling off) is the biggest issue.

2. Comparison among three method

We tried three kinds of polishing technique. The first one was using iron lap and fine diamond powders with rather high speed rotation that is the way to be used for sharpening the diamond tools or brightening jewelry which is single crystal.

The second one was using resinoid bond diamond wheel that is widely used in machining sintered polycrystalline diamond tools. However in this study, constant pressure type grinding like lapping was adopted to avoid strong force to the film. The experimental setup was almost same as drawn in Fig.1 except using diamond wheel instead of quartz glass.

The last one was ordinary conditioning ring type plain polishing with unique combination of glass disc tool with very fine silicone dioxide (SiO_2) powders. Fig.1 shows a setup of the method. The reason of using glass disc or SiO_2 is expectation of oxidization.

Table1 shows features of the three methods. Polishing experiments by three ways were performed. The specimens were CVD diamond films deposited upon silicon wafers.

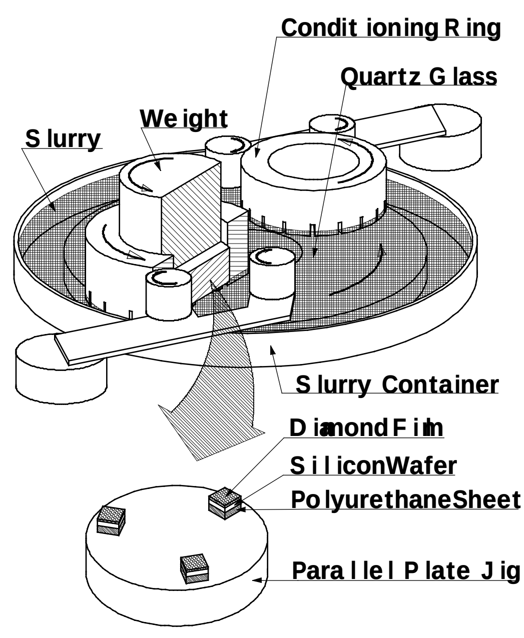

Fig.1 Setup of polishing machine (Conditioning ring type)

Table 1 Features of three smoothing method for CVD diamond film

*Type**	*Tool*	*Abrasive*	*Depth of cut*	*Tool rotating speed*	*Machining loci*
A	Steel	Diamond	Constant pressure	High	One direction
B	Diamond wheel (resinoid bond)	SiO_2	Constant pressure	Low	Multi direction
C	Quartz glass	SiO_2	Constant pressure	Low	Multi direction

* *A: Polishing method for single crystalline diamond*
B: Grinding under constant pressure
C: Conditioning ring type plain polishing

The first (A) and the second (B) attempts did not succeed. The exfoliation occurred in these processes and it was not able to get good surfaces.

In the last process (C), the exfoliation never occurred and better surface was obtained. In the process the oxidization generated by mechanical friction (tribo-chemical reaction) was expected. The reaction could aid the smoothing without peeling off. Fig.2 shows a SEM photograph of the diamond film polished by the last way (C). You can see that some wear was happened and only the peak was removed.

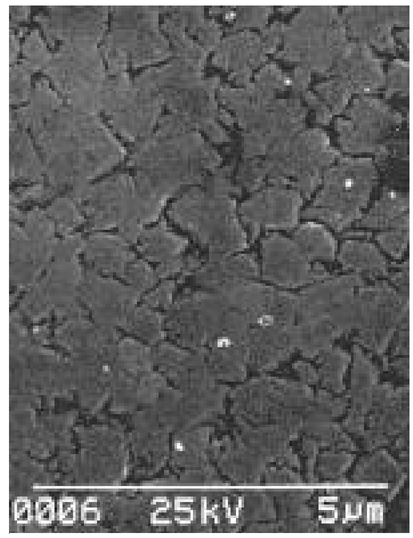

Fig.2 SEM photograph of polished diamond

3.Process parameters in glass disc polishing

To clarify the effect of each process parameter or to search an optimum polishing conditions in the glass disc polishing, some experiments were conducted. Table 2 shows the experimental conditions. Standard polishing condition was the combination of the glass disc tool and the SiO_2 abrasive. Zygo New View 100 measured surface roughness of the polished diamond film. We investigated the effect of tool material, abrasive material, slurry density, machining load and size of abrasive.

3.1.Tool material

Fig.3 shows the experimental results for the tool material. The horizontal axis is machining duration, and the vertical axis is the surface roughness of the diamond film at each time. We tried both polyurethane and cast iron disc as a tool in comparison with quartz glass. SiO_2 was used as abrasive at each experiment. In the case of the cast iron disc, exfoliation occurred during polishing. Between two other materials the glass disc showed better surface roughness.

Table 2 Experimental conditions

Machine	Conditioning ring type plain polishing machine
Tool	Quartz glass Polyurethane Cast iron
Abrasive	9, 14, 55nm SiO_2 30nm TiO_2
Slurry density	0(pure water), 2, 4, 10wt%
Polishing pressure	100, 300, 500kPa
Polishing speed	14m/min
Polishing duration	Up to 3.5hr
Surface roughness measurement apparatus	New View 100 (Zygo)

3.2.Abrasive material

To comparison with SiO_2 powder, we tried using TiO_2 powder and no powder condition where polishing was done with pure water only. Fig.4 shows the result. Using the SiO_2 powders shows the best result and there is almost no difference between the other two conditions. The SiO_2 abrasive works the best for smoothing

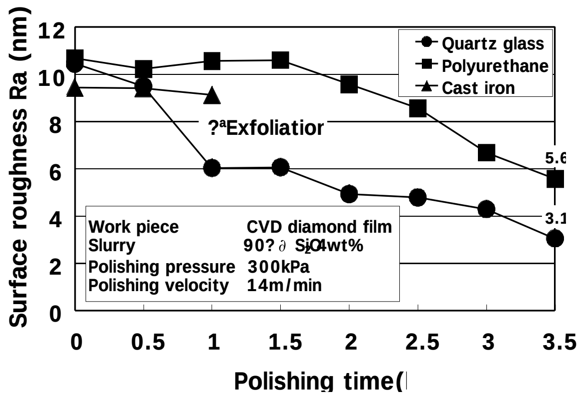

Fig.3 Effect of polishing tool

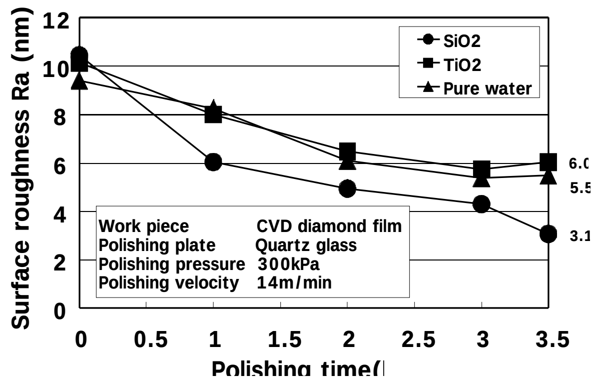

Fig.4 Effect of abrasive material

the diamond film.

As even glass disc with pure water only (without any powders) can smooth the diamond film of 10nmRa surface to less than 6nmRa, it is clarified that the glass disc itself acts some effect to smooth the diamond. The main component of the glass is SiO_2 as well. Some action between SiO_2 in the glass disc or from the abrasive and carbon atoms in the diamond takes a great role to remove the diamond from only the summit area.

3.3.Slurry density

Fig.5 shows the experimental results to investigate the influence of slurry density at the combination of quartz glass disc and SiO_2 abrasive. Higher the density is, better the surface becomes. In the case of density of 10%, 2.4nmRa surface could be realized. We think viscosity of the slurry may affect some extent as higher density slurry shows more viscosity.

3.4.Machining load

Fig.6 shows the effect of polishing pressure at glass disc and SiO_2 abrasive combination. Higher pressure condition can get better surface roughness. We think that contact ratio between SiO_2 abrasive and diamond surface becomes higher when more loads are supplied and the rate can accelerate the chemical action on the surface.

3.5.Size of abrasive

Fig.7 shows the influence of the abrasive size. It shows there is almost no effect of the size. If the smoothing action is thought to be mechanical, the diameters of the abrasive affect more. However as the action is thought to be some

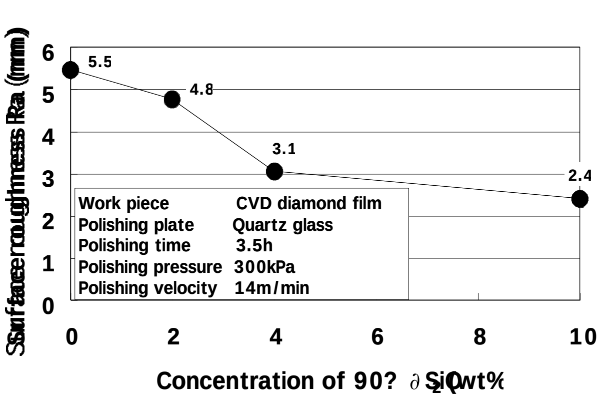

Fig.5 Effect of slurry density

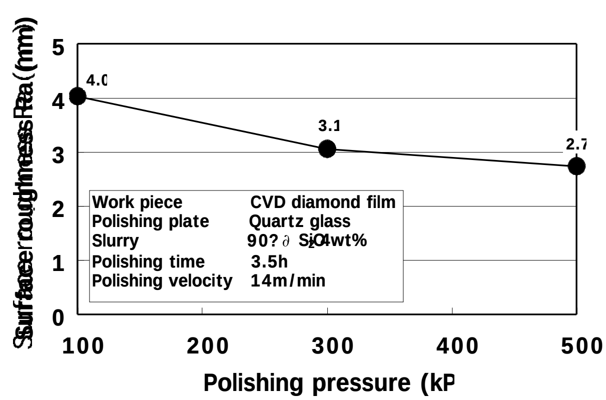

Fig.6 Effect of polishing load

chemical action, it can be convinced that the powder size has no effect.

4.Conclusion

1) The combination of glass disc and SiO_2 powder on ordinary conditioning-ring-type plain polishing machine is a good choice to smooth the diamond film surface.
2) Under the condition any exfoliation cannot be occurred.
3) Both the glass disc and the SiO_2 powder contribute to smooth the surface.
4) High slurry density and high machining pressure is preferable.

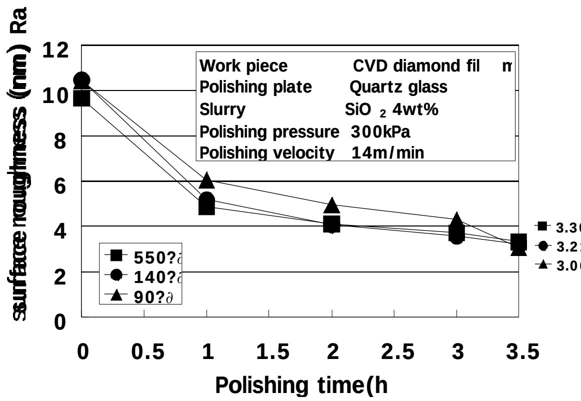

Fig.7 Effect of abrasive size

5) The size of SiO_2 powder has no effect to smooth the diamond. (within our experimental conditions)
6) Under the best combination, surface roughness of 2.4nmRa can be obtained.