Precision grinding of hard and superhard materials with CVD diamond grinding tools

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Abstract

Diamond abrasive layers produced by chemical vapour deposition (CVD) have demonstrated their high potentials as grinding tools. Besides the achieved superb workpiece surface qualities, the low wear rates of the tools show a further important advantage. Wear rate of CVD diamond layers were up to 80 times lower compared to wear rates of standard fine grained diamond grinding wheels demonstrating the outstanding tool life. Additionally, it has been shown that worn CVD diamond layers can be resharpened by additional, short CVD coating processes. The topography after recoating was nearly identical to the initial deposition processes and grinding performance is comparable.
This contribution will present the newest results of grinding tests on optical glass (N-BAK2) and alumina as well as the application of recoated tools. The low wear rate of CVD diamond abrasive layers immediately recommends them for the machining of hard and superhard materials.

1 Introduction

Microcrystalline CVD diamond abrasive layers have shown their potential in different precision grinding tests. Both extremely high workpiece quality and excellent low tool wear rates were achieved, e.g. by Venkatesh et al. and Suzuki et al. [1, 2]. Here, silicon carbide base bodies have been coated with rough microcrystalline diamond by CVD. The grinding wheels have been investigated concerning layer topography and machining performance. The grit protrusion of the layers varied between 3 and 8 µm with an exceedingly high number of single cutting tips of the CVD diamond abrasive layer (density up to 73,000 mm^{-2}). Furthermore, an excellent sharpness of the single cutting tips was obtained, i.e. a cutting edge radius of approx. 20 nm measured with SEM. Optical workpiece quality was achieved after grinding of optical glass N-BAK2. Alumina and cermets could also be machined with outstanding surface qualities, layer delaminations or breakage of cutting tips has not been observed [3].

2 Experimental results

2.1 Experiment specifications

CVD diamond grinding wheels were experimentally compared to standard fine grained grinding wheels (metal D12 and resin bonded MD25 diamond grinding wheels) in face grinding experiments on a precision machine tool (fig. 1) for machining optical glass N-BAK2. The glass samples were ground with 5% oil-in-water emulsion at process parameters of cutting speed $v_c = 10$ m/s, depth of cut $a_p = 0.01$mm and feed rate of $v_w = 0.5 – 10$ mm/min.

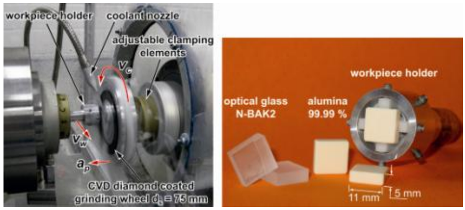

Figure 1: Experimental setup (left) and workpieces (right).

2.2 Grinding results

By employing the CVD diamond grinding wheels compared to the standard grinding wheels essentially better surface roughnesses Sa down to 15 nm and S10z down to 91 nm were achieved (fig. 2).

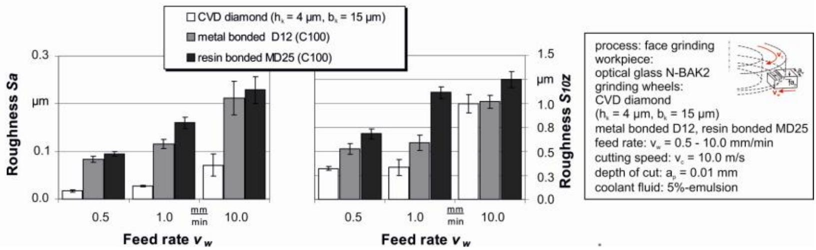

Figure 2: Surface roughness of the optical glass ground with CVD diamond coated and standard grinding wheels.

Optical microscope photographs of the glass specimens show a very low sub-surface damage of the workpieces ground with CVD diamond wheels. This implies that nearly ductile removal mechanisms are dominating (fig. 3, left). In contrast, the glass specimens ground with standard fine grained diamond grinding wheels show brittle material removal mechanism with a high number of material outbreaks (fig. 3, center and right).

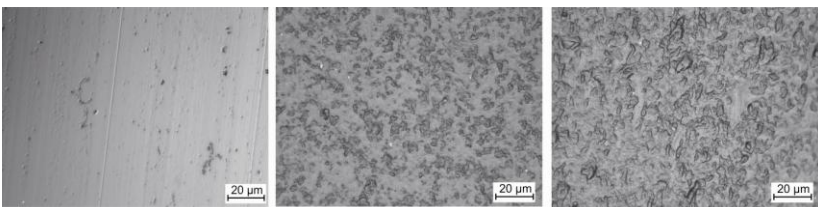

Figure 3: Glass surfaces (optical microscope) ground with CVD diamond (left), metal (center) and resin (right) bonded grinding wheels.

Furthermore, CVD diamond grinding tools show a greater lifetime than grinding wheels with conventionally bonded diamond grains. This could be proven in experiments on alumina (fig. 4). After a material removal of about 370 mm³ the metal bonded D12 wheel shows a ratio of removed workpiece volume to the grinding layer wear volume (G-ratio) of 330. In comparison, CVD diamond tools exhibited a G-ratio up to 3,300.

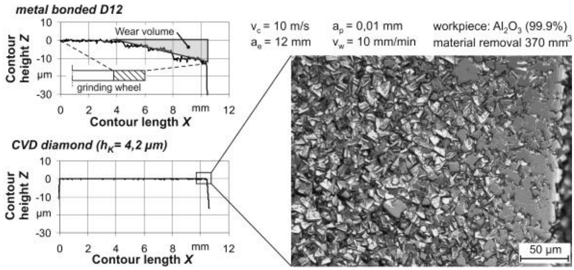

Figure 4: Resulting tool wear of standard metal bonded and CVD diamond wheels.

The adhesive strength of the CVD diamond grinding layer is also strong enough to grind hard materials like alumina under tougher cutting conditions (a_p = 0.5 mm, v_w = 10 mm/min).

Subsequently, in a recoating process (see section 3) the worn CVD abrasive layer sections can be re-established with the original topography. Thereby, the recoated grinding wheel exhibits a comparable process behavior as in initial state. Nearly identical surface qualities are maintained (fig. 5).

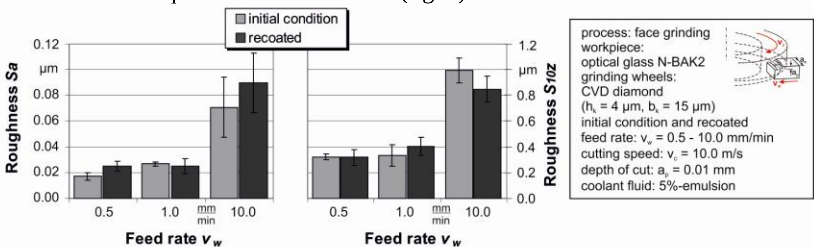

Figure 5: Surface roughness of optical glass ground with initially coated and recoated CVD diamond wheels.

3 Recoating

A dressing or truing of CVD diamond grinding layers cannot be performed as it is possible with most conventional bonded diamond grinding layers. These contain a multitude of grains above each other so that fresh grains can be brought to the surface as new, active abrasives. Compared to that, a CVD diamond layer has only one level of roughness. If the crystallite tips are worn there is no possibility to bring out new, unworn crystallites. To overcome this limitation, a new method of re-sharpening was investigated to enable a re-use of CVD diamond grinding tools.

Worn CVD diamond grinding wheels were exposed to an additional diamond chemical vapour deposition process. Under the same deposition conditions as during the initial coating process the worn crystallite tips grew up in a way that the crystallite flattenings disappeared. It was observed that crystallite tip shapes were retrieved that showed a similar topography as an unworn layer. Roughness measurements show that worn areas reached the same Ra value was as unworn areas (see fig. 6). These were also exposed to the additional deposition process but did not increase their roughness significantly. That means that the flat diamond faces grow much faster than the inclined faces.

This mechanism enables the resharpening of worn CVD diamond grinding tools. It was demonstrated that the performance of resharpened layers is the same as with new CVD diamond layers (see section 2). The recoating process needs only app. 5 % of the original deposition time. This enables a very economic solution for the application of CVD diamond grinding tools.

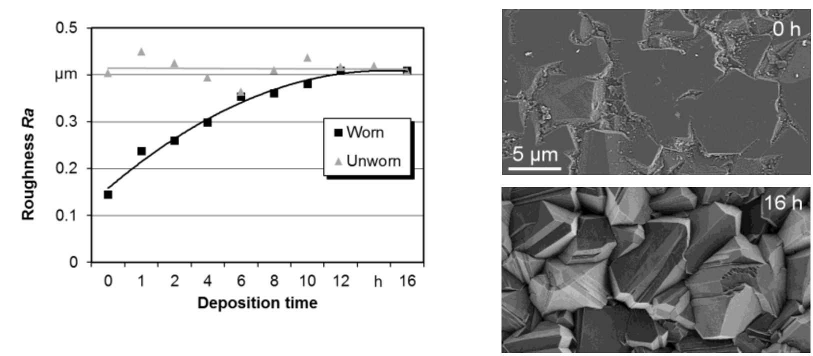

Figure 6: Recreation of CVD diamond layer roughness during recoating.

Acknowledgement

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