Precision Grinding with CVD Diamond Coated Dicing Blades

D. Miletic[1], J. Gäbler[2], L. Rissing[1]
[1]*Institute for Micro Production Technology, Center for Production Technology, Leibniz Universität Hannover, Germany*
[2]*Fraunhofer Institute for Surface Engineering and Thin Films, Germany*
miletic@impt.uni-hannover.de

Abstract

This paper presents the use of a new kind of dicing blades for the machining of various hard and brittle materials. The dicing blades have an aluminum nitride ceramic (AlN) base body, which is coated with rough, microcrystalline diamond deposited in a Chemical Vapor Deposition (CVD) process. These films feature neither pores nor a binder. The sharp edges of the crystallite tips act as micro cutting edges during the grinding process. Some various materials (e.g. AlTiC, SiC) were used for the tests to prove the stability of the blade and of the diamond coatings during dicing.

1 Introduction

Ultra-precision machining processes become more and more important for the development of semiconductor devices and within the growing field of MEMS (Micro Electro-mechanical Systems), e.g. for the cutting of HDD sliders or wafer dicing for micro sensors and actuators. Besides, the spectrum of the applied substrate materials (e.g. some ceramic materials like SiC und AlTiC) is extended. The tools currently used for these machining processes are high-precision grinding wheels (dicing blades). The dicing process is executed on ultra-precision machines, so-called "dicing saws". Dicing blades are typically fabricated by sintering or electroplating, where the bond material is a metal. In case of a resin bond, the dicing blade is manufactured by compression-moulding at the respective cross-linking temperature of the resin. The abrasive grains are usually made of diamond or cubic boron nitride (c-BN).

Every type of dicing blade is eligible for a certain machining assignment. The dicing blades with metal bond are becoming blunt with the time. Thus, they have to be conditioned in order to be applied further on. These dicing blades are normally used for the cutting of Si. On the other hand, the dicing blades with resin bond resharpen themselves (self-dressing) during the machining process, but their wear is very high. The novel dicing blades have no binder and a very high density of micro cutting edges so that they feature a higher strength and hardness compared to conventional dicing blades. Therefore, they are eligible for the dicing of brittle work piece materials with higher hardness, such as SiC and AlTiC.

2 Manufacturing process of the dicing blade

The new dicing blade consists of two components: a base body made of AlN and a diamond coating fabricated by a CVD process. The AlN base body is ring-shaped and manufactured by grinding on the basis of a thin AlN plate. AlN is chosen because of its high mechanical, thermal, and chemical stability [1]. Furthermore, it is suitable for CVD diamond coating. The main challenge during the manufacturing of the base body is to achieve a smooth surface and the undamaged edges of the outer ring circumference (Fig. 1). These aspects are the most responsible ones for the cutting process. The diamond coating conforms to the edge chipping of the base body. This influences the surface quality of the workpiece. The AlN rings are coated with a diamond layer by hot-filament activated CVD. After a seeding with micrometer-sized diamond crystallites the deposition takes place in a hydrogen atmosphere with 1.8 % methane at a pressure of 2,000 Pa. The total gas flow was 4,000 sccm. Metal filaments are placed above the substrates and are resistively heated to 2,200 K to initiate the chemical reactions needed for the absorption of carbon atoms on the substrate surface. Thus, microcrystalline diamond layers were deposited with various film thicknesses and sizes of the crystallilte tips by a variation of the deposition time. In order to achieve electrically conductive layers, which are necessary for the setting-up of machining parameters, 40 sccm of a boron-containing gas mixture (1 % $(CH_3)_3B$ in H_2) was added during the deposition causing a diamond layer resistance of app. 1 mΩcm.

3 Experimental

The tests were carried out on a dicing saw Disco DAC551. The purpose of the initial tests was to prove the stability of the blade and the diamond coatings. The blade was placed into an adapter, which was then mounted onto the machine spindle (Fig. 2). Due to the electrically conducting diamond coating, the setting-up of the machining parameters could be done successfully. 30 mm long chips made of Si, SiC, and AlTiC were used as workpieces. They had a thickness of 0.525 mm, 1 mm, and 1.2 mm, respectively. The chosen process parameters are typical for these kinds of materials (Table 1).

a) 

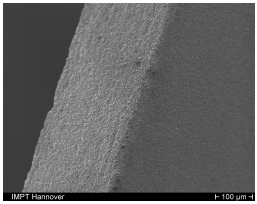
b) 

Figure 1: Coated dicing blade: a) Top view, b) SEM image of the ring circumference

a) 

b) 

Figure 2: Experimental set-up: a) Dicing blade in flange; b) Machining sequence

Table1: Process parameters

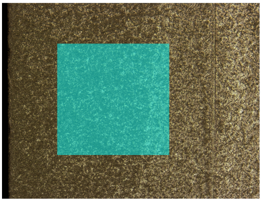
Parameter / Material	Cutting speed [m/min]	Cutting depth [mm]	Feed rate [mm/s]
Si	3,487	0.525	2.0
SiC	3,487	0.5	0.5
AlTiC	3,487	0.6	0.5

The wear of the dicings blades was analysed with a scanning electron microscope (SEM) before and after the cutting process. The dicing blades showed resistance to the deformation and the vibration during the machining process and did not feature any measurable wear. However, the chipping of the Si samples was higher compared to cutting with conventional metal bond blades.

Since it is possible to manufacture various diamond “grain” sizes using CVD processes, the influence of the “grain” size on the surface quality was investigated in further tests. Two blades with various “grain” sizes were used:

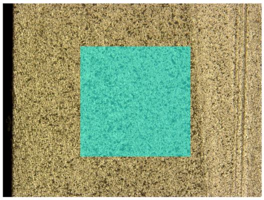
- Dicing blade CVD 1: mean maximum crystal width b_k = 10 µm, mean maximum crystal height h_k = 2.6 µm
- Dicing blade CVD 2: mean maximum crystal width b_k = 6.3 µm, mean maximum crystal height h_k = 2.6 µm

For this purpose, the AlTiC samples machined with the parameters listed in Table1 were used. For the surface analysis of the AlTiC samples, confocal laser scanning microscopy (CLMS) was applied (Fig. 3). The analysis delivers just relative results, because they depend on the size of a certain observing area. The measured arithmetical mean height of the surface *Sa* were compared with those obtained by AlTiC samples cut with a conventional dicing blade (Table2). The conventional blade features a resin bond and diamonds with a diameter of 45 µm.



	Sz	Sa
Seg. 1	21.982um	1.407um

a)



	Sz	Sa
Seg. 1	18.995um	0.700um

b)

Figure 3: CLMS cut analysis using: a) dicing blade CVD 1; b) dicing blade CVD 2

Table2: description

Dicing blade	2.187-8-45H (resin bond)	Dicing blade CVD 1	Dicing blade CVD 2
***Sa* [µm] (arithmetical average)**	1.497	1.356	0.695

By applying the same process parameters the smoother surfaces were achieved using the dicing blade with the smaller "diamond grains" (dicing blade CVD 2) compared to the dicing blade with the bigger "diamond grains" (dicing blade CVD 1). On the other hand, the surfaces achieved using the conventional blade with the resin bond show the highest value of *Sa*.

4 Conclusion

The novel dicing blades with the AlN base body and CVD diamond coating show a high resistance to deformation and vibration during the machining process. They did not feature any measurable wear during the machining of the hard and brittle ceramics SiC and AlTiC. By adjusting the "grain" sizes of coatings it is possible to influence the surface quality of a work piece.

References:

[1] Bandyopadhyay, S., Biswas, S.K., Maiti, H.S.: Nitride & Oxy-nitride Ceramics for High Temperature and Engineering Applications, Key Eng. Mat., Vol. 395, pp. 193-208, 2009