Dicing concept for mechanical structured materials and multi-layer-specimens

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Abstract

Increasing efficiency for dicing of hard and brittle materials still represents a major challenge for ultra-precision machining. At the same time is dicing the most effective technology for structuring of material composites or stacks consisting of different materials. This paper describes a new approach to structure multi material stacks by using specially adapted dual dicing blade concept with special remark on increasing form accuracy and facilitating miniaturisation. The dual dicing concept is further expanded for structuring of ductile materials and multi-material specimens.

1 Introduction

Dicing of hard and brittle materials such as advanced ceramics, glass and silicon is used in many industries. Functional ceramics and single crystals are extensively used in the production of electric, electronic, magnetic and optical components for high performance systems such as transducers, resonators, actuators and sensors. Ultra precision machining of hard and brittle advanced ceramics like Al_2O_3, Al_2O_3-TiC or SSiC is associated with high tool wear and high processing time [1, 2]. The application of the dual-blade dicing concept [3] on structuring of single and multi-layer specimens is a known technique to increase the production volume and efficiency. The chip removal by single-blade grinding process is a very complex process [4]. Due to the undefined cutting edges, the cutting forces and process quality are influenced by diverse process parameters. The most important of these parameters are the tool composition (binder material and an abrasive) and infeed (a_e). The dicing can be described as a combination of circumferential (peripheral) and sidewall (lateral) grinding mechanisms. Figure 1a shows the lateral grinding part of the single-blade dicing process for specified infeed a_e. According to this assumption, the model can be extended for the case of dual-blade dicing as shown in

Fig. 1b. To evaluate this assumption, the dual-blade dicing tests on different multi-layer materials and crystal materials like silicon are executed.

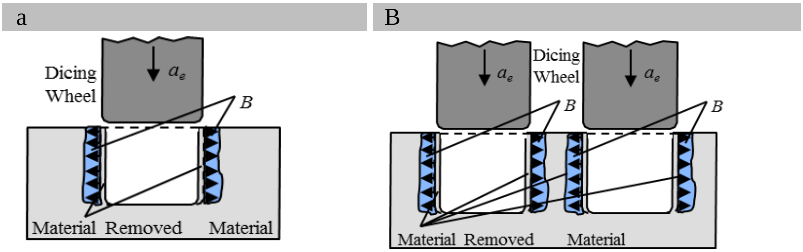


Figure 1: Lateral Grinding process of a) single and b) dual dicing

Based on the power consumption analysis, the dicing blade sidewall (lateral grinding) takes a smaller part of the total applied load [2]. Nevertheless, this part of the removal mechanism is responsible for the form accuracy of the sidewalls and is crucial for prediction of the chipping behaviour and the distribution of cutting forces (B).

2 Experimental

This paper shows a dicing strategy executed on stacks consisting of combinations of anodic bonded silicon carbide, monocrystalline silicon and borosilicate glass. The multi-material-specimens are bonded on a heating plate with 450°C, by applied voltage of 1.2 kV. Dicing was done on an ultra-precision dicing machine DISCO DAC551 with a spindle diameter of 2 inch. For the tests, metal-bonded dicing blades with thickness of 100 µm and 200 µm and an outer diameter of 55 mm were used. The dicing blades feature a grit of 5 µm, 9 µm and 15 µm, respectively.

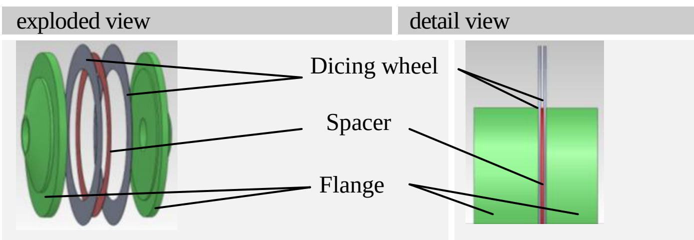


Figure 2: Dual dicing blade setup

In Figure 2, the setup for a dual dicing blade is shown. The spacer between the two dicing blades features an outer diameter of 50 mm and two thicknesses of 50 µm and 100 µm. The spacer thickness and diamond protrusion determines the size of the structure after dicing.

3 Results

The first investigations are made in monocrystalline silicon as a typical brittle material. The comparison of dicing with single and dual blades shows that the chipping of the single-blade process is higher than the dual-blade process. The effective spacer distance for 100 µm spacer combined with 15 µm grit 130 µm and for 9 µm grit 115 µm.

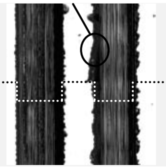
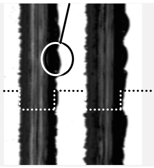
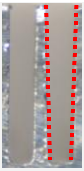
dual dicing chipping	single dicing chipping	Parameter
		• v_f = 0.5 mm/s • a_e = 1 mm • v_c = 58 m/min • blade 100 µm thickness with 15 µm diamond grit, space = 100 µm
sidewall angle	sidewall angle	• v_f = 0.5 mm/s • a_e = 2 mm • v_c = 58 m/min • blade 100 µm thickness with 9 µm diamond grit, space = 100 µm
		

Figure 3: dicing result of silicon

Because of the lower strength of silicon, this material tends to chipping at the cutting kerf. This characteristic makes it easy to compare an amount of brittle removal caused by dicing with single and dual-blades (Fig. 3up). By dicing with dual-blade concept, a chipping could be reduced for 20% comparing to single-blade process. The right side of the cutting edge offers a higher chipping, because of the diamond protrusion on the sidewall of the dicing blade. Furthermore, an effect on the form accuracy of the sidewalls is investigated (Fig. 3down). The results show a strong dependence between chipping and the generated structure size. The outer sidewalls of the cutting groove feature a lower angle on the outer sidewall of the kerf (<1°) by dicing with dual blades. For dicing with single blades an angle of 2°-3° is measured.

The stacks made of different materials are efficiently structured and separated (200 µm dicing blade, 15 µm diamond grit). This result shows the possibility to generate and modify stacks made of silicon and Pyrex (Fig. 4a), monocrystalline silicon carbide (6H SiC) serving as an active element (semiconductor) with a sintered silicon carbide (SSiC) serving as a passive element (heat sink Fig. 4b). The residue of bonded 6H SiC wall (Fig. 4b) shows that the bonding forces are higher than the cutting forces. The 6H SiC wall structures breaks above the bond due to the kerf chipping in the 6H material without bond failing. The cutting forces of lateral grinding are lower than the bonding forces after anodic bonding, but higher than the structural stiffness weakened by brittle chipping.

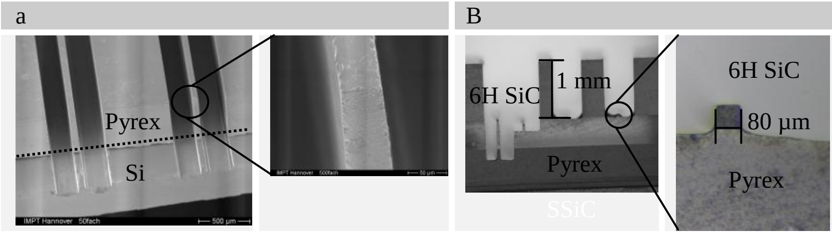


Figure 4: bonded stacks after dicing, a) Si-Pyrex and b) 6H SiC- Pyrex - SSiC

The dicing of hard and brittle materials (SiC and Al_2O_3) leads to increasing of the structure width by dicing with 100 µm spacer and 15 µm grit from 130 µm to 190 µm. This is a result of the dicing blade protrusion (2-2.5 mm) in the flange.

4 Conclusion and Outlook

The results show a different cutting behaviour of dual-blade dicing setup and single-blade setup. With a lower chipping by dual-blade concept, the structures can be smaller and deeper diced. By implementing the dual dicing concept for structuring (profiling) of multi-layer-specimens, high aspect ratio micro structures can be fabricated. The chipping has to be lower than 10% of the structure (protrusion) thickness, to prevent breakage. This first steps for a more productive concept are made by this work. The next task is to develop an optimal dicing process with the best process parameters for other multi-layer materials like LTCC (low temperature cofired ceramic), PZT (lead zirconate titanate) and FR-4 PCB and the characterisation of the bond strength and the cutting forces. The influence of the dicing blade protrusion during dual dicing has to be more investigated.

References:

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