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Reverse Engineering of Dicing Blade to Prolong Its Lifetime

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Abstract: This paper presents a study on the TiAlN hard coating was deposited on the existing dicing blade with the PVD technique using RF and DC magnetron sputtering. The surface morphologies of the dicing blade were analyzed by field emission scanning electron microscopy (FESEM) and material properties were investigated by using energy dispersive spectroscopy (EDS). The nanoindentation parameters such as hardness and Young's modulus were investigated by nanoindenter (Hysitron Ti Premier) testing to characterize the hard coating on the dicing blade. The result shows the material properties of the dicing blade were nickel bond diamond dicing blade and the corresponding hardness of existing dicing blade measured by nanoindentation is around 2.83 GPa.

Keywords: Dicing Blade, TiAlN, Nanoindenter, Hardness, Hard Coating, FESEM, Magnetron Sputtering

1. Introduction

Dicing blades are a sort of tool that uses a high-speed spindle fitted with an incredibly thin blade of diamonds. Hard-brittle materials like ceramics, glass, quartz, wafers for semiconductors, silicon, and others is the material that commonly used for cutting by these tools. It is widely used for die separation and also for perfect, precise, partial and cut-through applications in the microelectronic industry [1]. Dicing blades are embedded in a bond matrix with diamond particles. They retain either resin bond (soft strength), sintered metal bond (medium strength), or electroplated nickel bond (hard strength) together with a binder. Any particle of diamonds embedded in the blade splits or splits gradually during dicing since it grinds material far away from the surface of the substrate, and new particles trapped in the matrix continuously give new sharp spots until the blade wears out.

The concentration of diamond particles and their size, together with the form and thickness of the matrix, make up the blade structure and directly affect the finish quality of a cutting job. Hard and brittle material requires a soft blade binder, while a harder matrix (nickel and metal sintered) is usually required for less brittle substrates. A bond matrix that is too soft can release diamond particles at an unreasonable rate compared to the material to be cut and may wear out very quickly (short life). On the contrary, a too hard bonding matrix would result in a small number of diamond particles released and therefore in low cutting capacity, repeated blade dressing will be needed to constantly expose next

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layers of fresh and sharp diamond particles [2]. The blade's high speed of rotation and the extreme friction of the diamond particles on the diced substrate surface generate a considerable amount of heat during dicing that needs to be evacuated. In order to thermally stabilize the cycle and boost the life of the blade hence the cooling water is supplied to the dicing blade nearby.

2. Materials and Methods

2.1 Materials

This section will describe each step that will be implemented in the project. In this research, the types of equipment used to carry out the experiments to achieve the desired objectives are as follows.

- Field Emission Scanning Electron Microscopy with Energy Dispersive Spectroscopy (FESEM-EDS)
- Nanoindenter
- RF and DC Magnetron Sputtering

2.2 Methods

In this research, the method that will be used to identify the types of material in the dicing blade is Field Emission Scanning Electron Microscopy with Energy Dispersive Spectroscopy (FESEM-EDS). One of the most flexible and well-known analytical methods is electron microscopy scanning (SEM). An electron microscope offers advantages compared to conventional optical microscopes, including high magnification, high focus depth, high resolution and sample preparation and observation facility. The opportunity to analyze smaller region contamination spots at electron accelerating voltages consistent with energy dispersive spectroscopy (EDS) in addition to the secondary electrons imaging.

Next, dicing blade hardness is measured using the nanoindenter. A nanoindenter is a principal component used in nanoindentation for indentation hardness tests. In this project, to investigate the hardness of existing dicing blade in the market and also measure the hardness test after the hard coating has been implemented.

Hard coating is one of the methods that can be implemented to improve the lifetime of a dicing blade. To improve their desired properties such as hardness, friction, wear resistance and corrosion resistance the implementation of hard coatings is very important. By using a sputtering machine, this method can be implemented. Magnetron sputtering has evolved rapidly over the last decade where it has become known as the process of choice for the deposition of a wide range of industrially relevant coatings [2].

3. Results and Discussion

The results and discussion section presents data and analysis of the study. The material properties in the dicing blade were obtained from FESEM-EDS and implementation of TiAlN hard coating using RF and DC magnetron sputtering and been analyzed by using nanoindenter for measured the hardness.

3.1 Investigate the material properties of the existing dicing blade

The material of the dicing blade is divided into three types such as sintered metal bond, resin bond and nickel bond diamond dicing blade. From the sample, which was given by the Lumiled company, firstly need to run an experiment to identify the types of material in the existing dicing blade to determine which group of the dicing blade belong between those three types. In order to do so, FESEM-EDS is a suitable machine that can be used to identify the material of the dicing blade. Below show the results obtained from the FESEM-EDS.

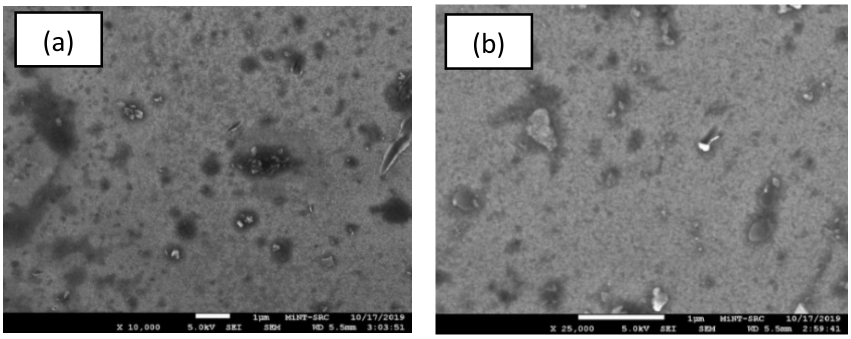
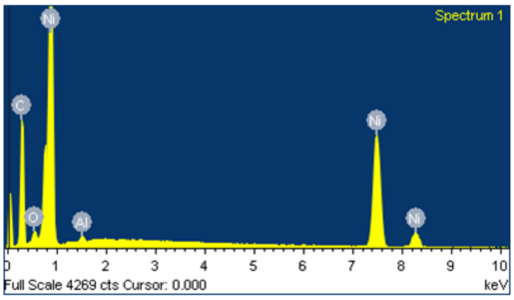
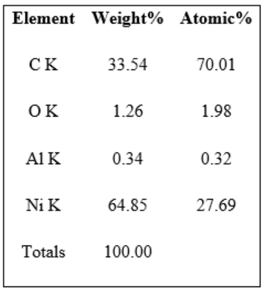


Figure 1: FESEM images of existing dicing blade. (a) 10000 magnifications; (b) 25000 magnifications

Figure 1 shows the field emission scanning electron micrograph of a dicing blade which shows the surface morphology of a dicing blade at different magnifications. Figure 2 shows the diamond abrasive distribution of the used dicing blade.





Element	Weight%	Atomic%
C K	33.54	70.01
O K	1.26	1.98
Al K	0.34	0.32
Ni K	64.85	27.69
Totals	100.00	

Figure 2: Result of EDS for existing dicing blade

EDS result shows that only carbon (C), oxygen (O), aluminium (Al) and nickel (Ni) elements were present. The result shows that the element of carbon is the highest which is 70.01 % followed by nickel element about 27.69%. Typically, the material of the dicing blade is made from the diamond. It can be proved from this result where the diamond is a solid form of the carbon element with its atoms arranged in a crystal structure called a cubic diamond. From the result obtained, it can be concluded that the type of material of the dicing blade is nickel bond diamond dicing blade because the presence of carbon and nickel element is high.

3.2 Investigate the hardness of existing dicing in the market by using nanoindenter

The Young's modulus (E) and hardness (H) in the nanoindentation test is derived from measurements of a hard element (indenter) of known properties and shape directly from the indentation force and the penetration depth. The hardness of the nanoindentation technique and the Young's modulus can be determined by the Oliver and Pharr method, where hardness can be defined as shown in Eq. 1. $P_{\max}$ is the maximum load applied and Ac is the maximum load contact area as shown in Figure3 [3].

$$H = \frac{Pmax}{Ac}, \quad \text{Eq. 1}$$

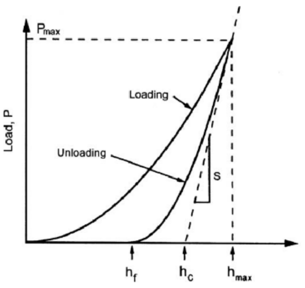


Figure 3: Load-displacement obtained from a nanoindentation test [4]

Berkovich is the indenter type that being used in this experiment and the maximum load is 1000 µN thus the time is 19 s. Furthermore, in the time period of 0 s keep the load below 1 µN. The initial contact zero of the pressure needle and surface was determined for the subsequent testing equipment to determine the indentation depth. The load increased from 0 to 1000 µN in the time period of 1.5-5 s. Next, the loading rate was 200 µN/s in the time period of 5 s-10 s, the maximum load was retained for 5 s to eliminate the thermal drift of the indenter. Finally, the indenter was withdrawn at a rate of 200 µN/s starting at 10 s and the load was 0 at 15 s.

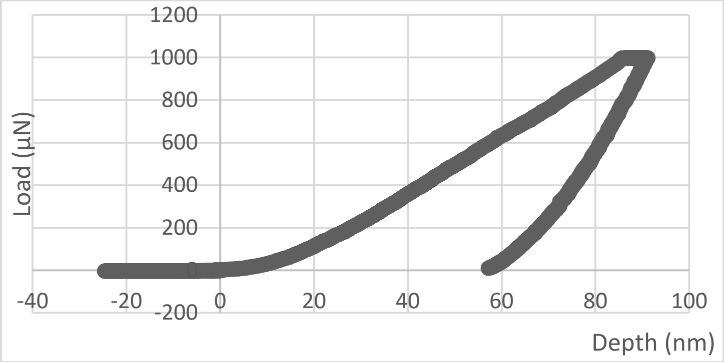


Figure 4: Result of nanoindentation test for existing dicing blade

Figure 4 shows the result of hardness test is 5.16 GPa and Young's modulus is 90.32 GPa. The average hardness of polished dicing blade is 2.83 GPa. As a conclusion, the result shows the improvement from the previous result which is from 100.12 MPa to 2.83 GPa in average. When the surface become smooth, it is more reliable when pressing an indenter into the dicing blade's surface.

3.3 TiAlN hard coating on dicing blade by sputtering technique and its characterization.

Hard coating is used everywhere in a wide range of applications including wear and corrosion safety for electrical, anti-reflective, and decorative purposes. The coatings studied in this research exhibit high hardness which makes them suitable for use on cutting tools as protective coatings. Since the 1980s TiAlN has been used in the metal cutting market. TiAlN was TiN's successor and introduced to improve TiN's poor oxidation behavior.

Coating deposition is divided into chemical vapor deposition (CVD) and physical vapor deposition (PVD). In this research were focused on PVD which is RF and DC magnetron sputtering method. During sputtering, highly energetic gas ions bombard the target material which the deposition material "spits out" into the substrate [5].

TiAlN was deposited on the substrate which is dicing blade by simultaneous RF magnetron sputtering of titanium (Ti) with 99.995% pure target and DC magnetron sputtering of aluminium (Al) and nitride (N) using RF/DC magnetron sputtering system (SNTEK PSP 5004 (09SN70)) using rf power supply. The substrates were put into the sputtering chamber and evacuated to 7 x 10-6 Torr (base pressure). The argon (Ar) was introduced into the chamber in order to achieve a pressure of 5mTorr once the vacuum was achieved. Pre-sputtering using Ar gas was performed to the target for 10 minutes before the deposition to eliminate impurities on the target. All the depositions in this pulse rf supply were performed at 200W power.

Ti target was powered by RF supply meanwhile Al target powered by DC supply. Then, Ti began to be deposited on the substrate as the first layer for about 15 minutes. After that, nitrogen was introduced, and nitriding began to produce TiN layer as a second layer and this process has taken about 60 minutes. The plasma changed colour from purple to pink with the presence of the nitrogen in the chamber. Next, to growth the TiAlN layer, this process was taken about 120 minutes and the total growth period was 3 hours. In this experiment were divided into 2 parameters (parameter A and parameter B). The only differences were the various flow rates of Ar and N2 which are 80 Sccm and 20 Sccm for parameter A and 70 Sccm and 30 Sccm for parameter B respectively.

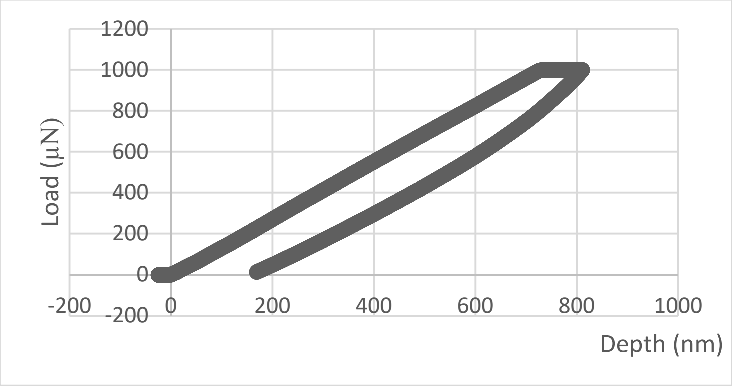


Figure 5: Result of hardness test for coated dicing blade A

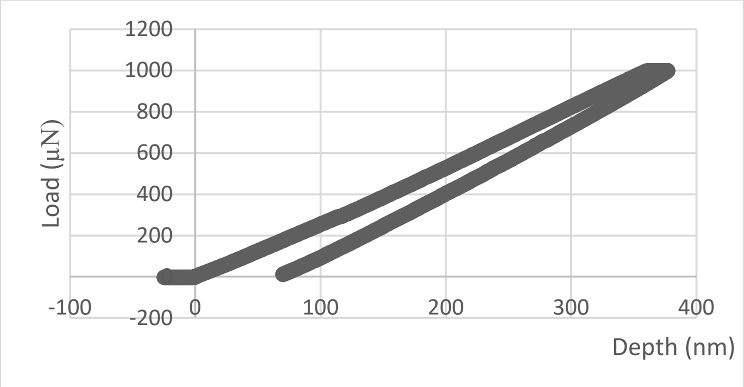


Figure 6: Result of hardness test for coated dicing blade B

Based on Figure 5, the hardness is 0.2 GPa and 0.76 GPa for Young's Modulus. The average hardness for coated dicing blade A is 0.12 GPa. Meanwhile, based on figure 6 the hardness is 1.3 GPa and 3.46 GPa for Young's Modulus. The average hardness for coated dicing blade B is 0.7 GPa.The hardness for uncoated dicing blade (unpolished) is 0.1 GPa meanwhile, the average hardness for coated dicing blade is 0.41 GPa. The hardness for TiAlN coating must be higher compared to the uncoated dicing blade.

According to the result of hardness for unpolished dicing blade shows in Figure 6, the hardness increases after being coated form 0.1 GPa to 0.41 GPa. Based on the previous studies, the hardness of TiAlN is 36 GPa. Possibly, the result can be improved by polish the dicing blade before TiAlN hard coating being deposited as done in the second experiment which determines the hardness of the existing dicing blade. Errors may occur if the test is not performed under appropriate conditions. The coating strength and adhesion to the substrate are essential for a sample with coatings. Unless the delamination or other damage to the coating occurs, the measured value of the hardness or the modulus of the young would be incorrect. Coated tools ensure better performance and protection against high mechanical and thermal loads generated by extreme temperature during the cutting process compared with uncoated tools.

4. Conclusion

As a conclusion, dicing blade had been studied to determine the material properties of existing dicing blade by using FESEM-EDS and determine the type of dicing blade which is nickel bond diamond dicing blade. To prolong the lifetime of a dicing blade, the implementation of hard coating has been done. TiAlN was deposited on the dicing blade by RF and DC magnetron sputtering. Nanoindentation measurement shows the hardness of existing dicing blade increase after been coated although the result still not achieved to 36 GPa for TiAlN hard coating. Generally, increasing the hardness of TiAlN would provide the cutting tools with a long service life thus high blade life will reduce the blade costs.

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