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Surface generation mechanism of ALON under ultra-precision grinding

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Abstract
The surface generation mechanism of Aluminum Oxynitride ($Al_{23}O_{27}N_5$ or ALON) under ultra-precision grinding were investigated in the present work. A series of nanoindentation experiments were carried out to research the mechanical properties of ALON firstly, the results showed that the various grain orientations and large grain size of ALON led to the nonuniform surface mechanical properties across the surface of workpiece. Secondly, the results of single-point diamond scratching verified that ALON was removed in ductile range at a smaller scratch depth (h_{max}=2μm), besides, different forms of surface removal appeared during the scratch process with the increase of scratch depth. Finally, the ALON ultra-precision grinding experiments were implemented, the results indicated that the differences in the grinding behavior of adjacent grains caused an obvious influence on the surface generation of ALON, in addition, the features observed in ALON surface are described and discussed in this paper.

Key words: ALON, Large grain size, Ultra-precision grinding, Surface

1. Introduction

Aluminum oxynitride (ALON) polycrystalline material can be widely used for engineering applications, because of its outstanding mechanical properties, as one of typical hard brittle materials, ALON is currently effectively machined only by grinding. And although ALON is polycrystalline, it has quite large grain size on the order of 150-250μm, therefore, different mechanical properties of adjacent grains may produce a lot of processing challenges to ultra-precision grinding[1].

In order to research the surface generation mechanism of ALON, this study firstly utilized the nano indentation to illustrate the mechanical properties across the surface of workpiece. Afterwards, single-point diamond scratching was carried out to simplify the grinding process and to determine grinding parameters. And then the surface generation mechanism of ALON under ultra-precision grinding was investigated by a novel etch method after grinding.

2. Experimental facility and processing parameters

The investigated ALON material used in this experiment were procured from Shanghai Institute of Ceramics, the workpiece material properties are shown in Table 1. For nanoindentation tests and single-point diamond scratching, the surfaces of workpieces were mechanically polished to a mirror finish.

Table 1 workpiece material properties

Workpiece	**ALON($AL_{23}O_{27}N_5$)**
Form	Polycrystalline
Grain size(micron)	100-250
Structure	Cubic
Hardness (kgf/mm)	1850
Young's Modulus(Gpa)	430
Density(g/cm³)	3.69
Dia of workpiece (mm)	30

2.1. Nanoindentation experiments

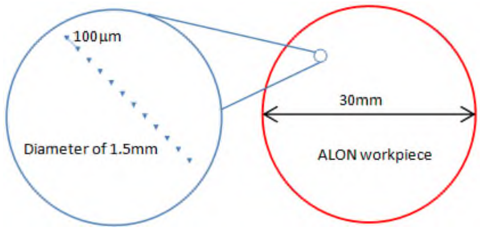

Figure 1. schematic of nanoindentation experiments

Nanoindentation experiments were performed using a nanoindentation tester (Nano Indenter G200) equipped with a diamond indenter at maximum loads ranging from 25 to 500 mN. With the load of 400mN and the holding time of 20s, a series of nanoindentations were conducted on the part of ALON workpiece surface every other 100 μm, as shown in Figure 1.

2.2. Single-point diamond scratching

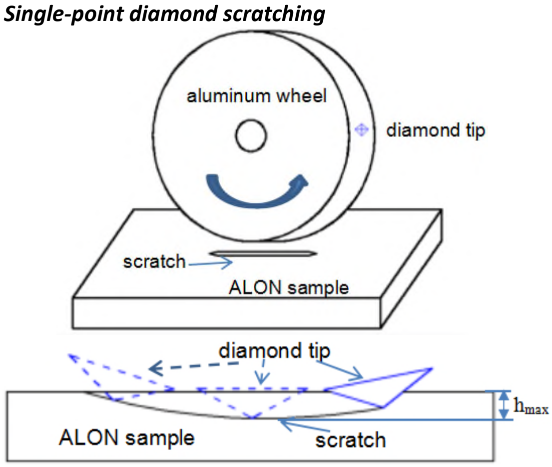

Figure 2. schematic of scratch test

Single-point diamond scratching were performed with a diamond tip that was fastened to an aluminum wheel, as shown in Figure 2, and the maximum scratch depths (h_{max}) were as follows: 2μm, 3μm, 4μm, 5μm.

2.3. Grinding experiment

Ultra-precision grinding of ALON was conducted on Moore Nanotech 350FG. Illustration of the grinding experiment platform is shown in Figure 3, and the grinding parameters are listed in Table 2. Afterwards, etching experiments of the ALON grinding surface were performed in situ.

Figure 3. experiment platform for ultra-precision grinding

Table 2 processing parameters

processing		parameters
grinding	feed	2μm
	feedrate	5mm/min
	cutting speed	237.2m/s
	wheel grit	7μm

3. Results and discussion

Figure 4 (a) shows the SEM micrograph of nanoindentation, and Figure 4 (b) illustrates that the surface mechanical properties of different ALON regions have large nonuniformity, the hardness is from 17GPa to 32Gpa and the modulus is from 350GPa to 395GPa. It illustrated that the various grain orientations and large grain size of ALON led to the nonuniform surface mechanical properties across the surface of workpiece.

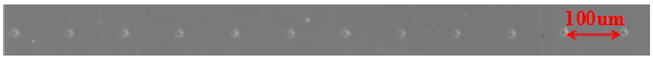

Figure 4 (a). SEM micrograph of nanoindentation

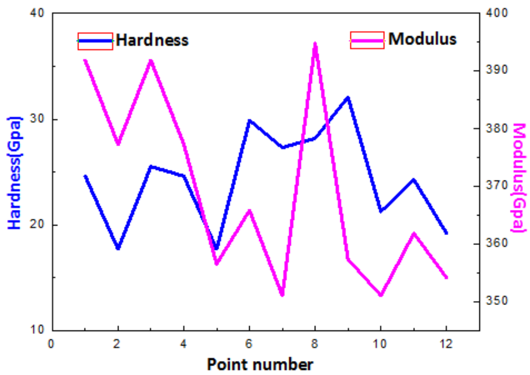

Figure 4 (b). the results of nanoindentation

Figure 5 shows SEM images from 4 scratches machined with different maximum scratch depths (h_{max}). These images indicate that there is an increase in the broken size with an increasing h_{max}, and there is the smallest crack when the h_{max}=2μm. Importantly, it is evident that the most serious breakout in each scratch does not necessarily appear at the center where is the maximum scratch depth, so the location of crack is not only affected by scratch depth but also affected by nonuniform surface mechanical properties.

In Figure 6, different forms of material removal appear across the ALON surface after ultra-precision grinding, in addition, an uneven distribution of plastic removal and brittle fracture are very serious. As the grain boundaries and the crystal microstructure of ALON appeared after eatching in situ, the big discovery was that the plastic removal and the brittle fracture were strictly located in different grains, as shown in Figure 7.

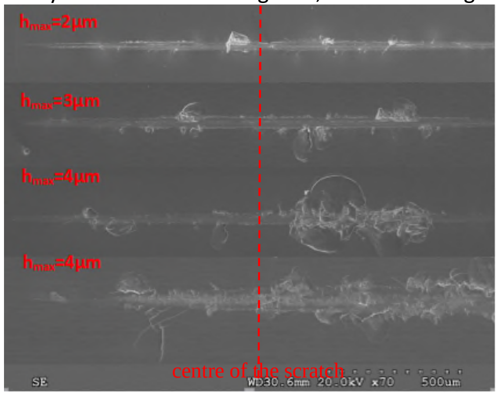

Figure 5. SEM micrograph of 4 scratches

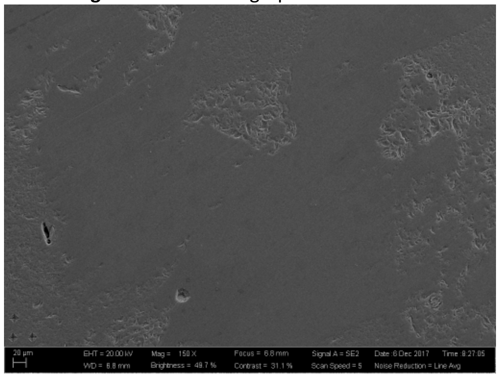

Figure 6. SEM micrograph of the grinding surface

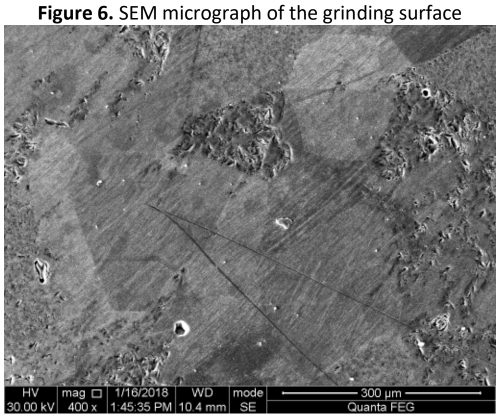

Figure 7. SEM micrograph of the grinding surface after etching in situ

4. Conclusion

This study has proved that ALON material has the nonuniform surface mechanical properties as a result of the various grain orientations and large grain size, and the nonuniformity leads to an distribution of plastic removal and brittle fracture under ultra-precision grinding. But there is still much further research need to be done for processing technic of ALON.

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References

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