Microcracking behavior of AlN ceramics in sliding test

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Introduction

Aluminum nitride (AlN) ceramics are used as components of semiconductor manufacturing equipments due to their excellent thermal conductivity, electrical insulation and stability in corrosive gases such as NF_3 plasma. However, when micro-scale defects on the AlN surface are generated by wear with other components, inhomogeneous corrosion occurs at their defects leading to shorten the lifetime of AlN components in such severe environments.

In this study, the damage generation behavior of various AlN ceramics is investigated by sliding test in combination with their mechanical properties.

Experimental Procedure

AlN ceramics containing different amount of Y_2O_3 and/or SiO_2 additives were prepared by hot-press sintering. The sliding test was carried out using the pin-on-disk configuration with a silicon pin at 360 °C in vacuum. After the sliding test, the number of grain boundary microcracks on the AlN surface due to friction was determined by a scanning electron microscopy (SEM).

The fracture strength of AlN ceramics was measured by a 4-point bending test. The fracture toughness and hardness were evaluated by the Vickers indentation method. The grain boundary fracture toughness was estimated from the fracture toughness value and a percentage of the intergranular fracture.

Results and Discussion

Fig.1 is the typical micrograph of the AlN ceramics after the sliding test. Silicon debris accumulation and microcracking of AlN were observed at the sliding tested surfaces. The amount of silicon debris accumulation was observed to be inversely proportional to the number of microcracks. The microcracks generated at the grain boundary were almost perpendicular to the sliding direction. The density of microcracks increased linearly with increasing the frictional force.

The material properties of various AlN ceramics and their relation to the density of microcracks were investigated. As the result, there was no good correlation between the density of microcracks and other mechanical properties such as fracture strength, toughness and hardness. However, the grain boundary fracture toughness was in a good correlation with the density of microcracks. The normalized density of microcracks, $\ln(N/P \bullet d^{1/2})$, where N, P and d are the density of microcracks, the applied load and the average grain size, is plotted in Fig.2 as a function of grain boundary fracture toughness, The normalized density of microcracks slightly decreased with K_{IC}^{gb} value (region I) and drastically dropped above 1.9 MPa·m$^{1/2}$ (region II). From these behaviors, the AlN ceramics with high K_{IC}^{gb} (region II) exhibit superior resistance to the silicon contact.

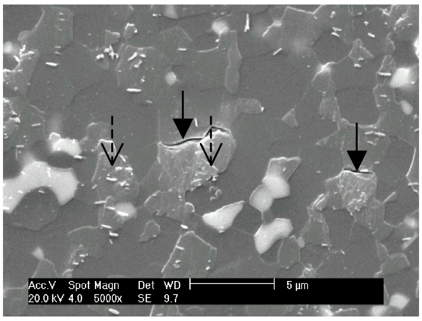

Fig.1 A typical SEM image of the sliding tested AlN surface. Solid arrows indicate grain boundary microcracks and broken ones indicate silicon debris.

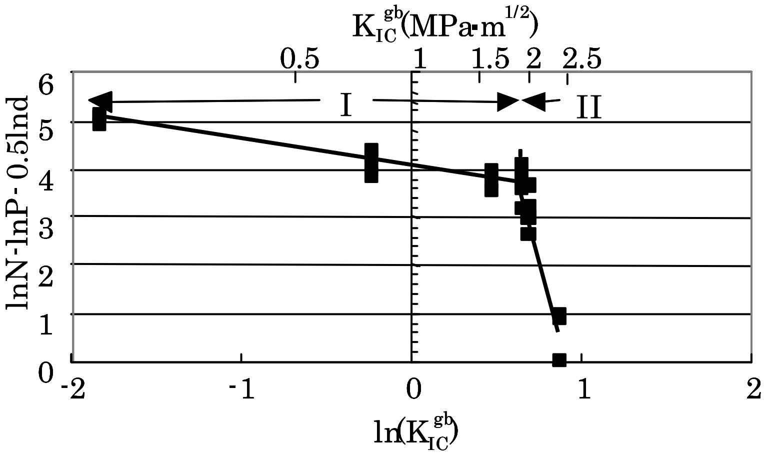

Fig.2 The relationship between the normalized density of microcracks and grain boundary fracture toughness.

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