Superfinishing characteristics of single crystal silicon with mechanochemical superabrasive stone containing $BaSO_4$ abrasive

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Abstract

In this study, superfinishing characteristics of single crystal silicon using vitrified bonded superabrasive stones containing soft barium sulphate ($BaSO_4$) abrasives were investigated. $BaSO_4$ can act as an oxidizing agent in superfinishing. A thermodynamic analysis suggests that $BaSO_4$ reacts with silicon forming oxides. Characteristic X-ray patterns revealed that layers that covered silicon heated with $BaSO_4$ abrasives consisted of silicon and oxide. On the basis of these results, vitrified diamond stones containing $BaSO_4$ abrasives were evaluated through superfinishing of single crystal silicon. It was found that the addition of $BaSO_4$ abrasives improved the dressing intervals of diamond stones. After finishing with diamond stones containing $BaSO_4$ abrasives, superfinishing characteristics of single crystal silicon with soft $BaSO_4$ stones were investigated. Results indicate that $BaSO_4$ stones can finish single crystal silicon to 1.5 nm Ra in 2 minutes under the condition that can promote chemical reactions.

1. Chemical reactions between barium sulfate and silicon

To examine chemical reactions between single crystal silicon and $BaSO_4$ abrasives, contact tests in vacuum were conducted. Single crystal silicon in contact with $BaSO_4$ abrasives and single crystal silicon without $BaSO_4$ abrasives were heated in vacuum at 400 to 550 degrees Celsius. Heating experiments showed that the surface of single crystal silicon in contact with $BaSO_4$ abrasives was oxidized at a certain temperature.

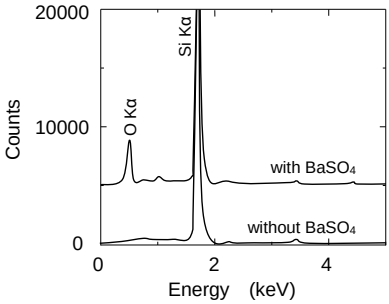

Figure 1. Characteristic X-ray intensity of silicon specimen after heating with/without $BaSO_4$ abrasives. (550 degrees Celsius)

In contrast, there was no change on the surface of single crystal silicon heated without $BaSO_4$ abrasives (Figure 1).

2. Experimental details

Two types of mechanochemical stones have developed in previous work [1]. First stone is a mechanochemical diamond stone containing $BaSO_4$ abrasives (SD / $BaSO_4$ stone). Second stone is a vitrified bonded $BaSO_4$ stone ($BaSO_4$ stone). Superfinishing characteristics of these stones were compared with conventional vitrified bonded superabrasive diamond stones (SD stone).

3. Performance of mechanochemical superabrasive stones

Superfinishing experiments (Table 1) showed that SD / $BaSO_4$ stones were able to produce roughness of 12 nm Ra in 1 minute from pre-finished surface of 70 nm Ra (Figure 2). After several minutes of superfinishing, surface roughness became worse and these stones needed to be dressed. SD / $BaSO_4$ stones had the longest dressing interval among the three stones (Figure 3).

Table 1. Superfinishing conditions.

Superfinishing pressure	0.43 MPa
Stone speed	64-254 m/min
Workpiece speed	22 m/min
Frequency of oscillation	6.7 Hz
Amplitude	0.5 mm
Superfinishing fluid	Dilute solution of rust inhibitor in water, Concentration=1%
Workpiece material	Si (100), 70 nmRa

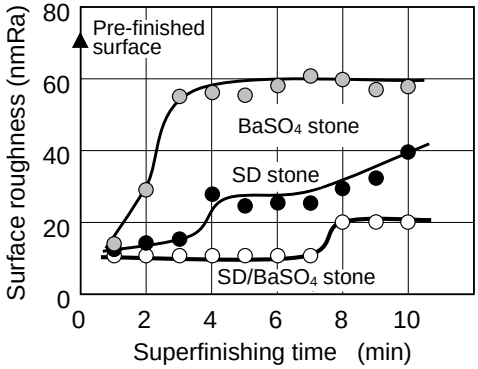

Figure 2. Comparison of roughness values of surfaces generated with SD, SD/$BaSO_4$ and $BaSO_4$ stones. (Stone speed: 64 m/min)

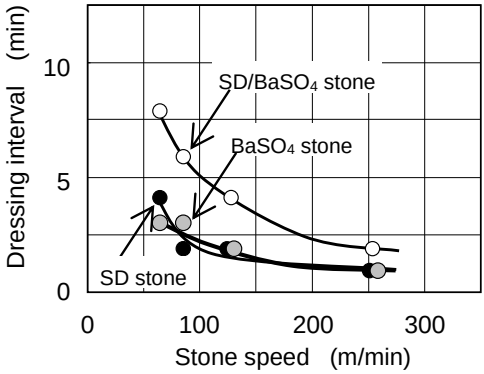

Figure 3. Comparison of dressing intervals of SD, SD/$BaSO_4$ and $BaSO_4$ stones.

After finishing with SD / $BaSO_4$ stones, superfinishing characteristics of single crystal silicon with soft $BaSO_4$ stones were investigated (Table 2). Results indicate that $BaSO_4$ stones can finish single crystal silicon to 1.5 nm Ra in 2 minutes under the condition that can promote chemical reactions between silicon and $BaSO_4$ abrasives (Figure 4).

This result seems to explain the effect of $BaSO_4$ abrasive addition into mechanochemical diamond stones (SD / $BaSO_4$ stone) as well.

Table 2. Superfinishing conditions.

Superfinishing pressure	0.56 MPa
Stone speed	127 m/min
Workpiece speed	22 m/min
Frequency of oscillation	6.7 Hz
Amplitude	0.5 mm
Superfinishing fluid	Dilute solution of rust inhibitor in water, Concentration=1%
Workpiece material	Si (100), 12 nmRa

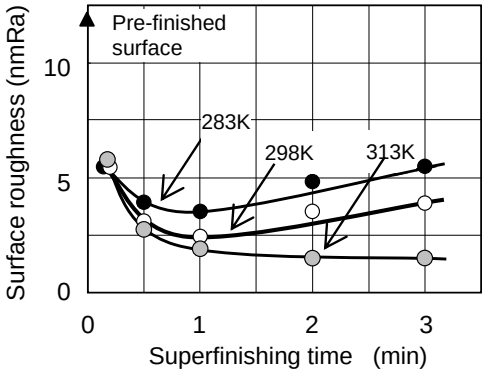

Figure 4. Comparison of roughness values of surfaces generated with $BaSO_4$ stones as a function of superfinishing fluid temperature.

4. Conclusions

Mechanochemical diamond stones containing $BaSO_4$ abrasives and vitrified bonded $BaSO_4$ stones were evaluated through the superfinishing of single crystal silicon. As $BaSO_4$ abrasives oxidize the surface of silicon, SD / $BaSO_4$ stones and $BaSO_4$ stones showed the following characteristics.

(1) SD / $BaSO_4$ stones can finish single crystal silicon to 12 nm Ra in 1 minute and have longer dressing intervals than conventional diamond stones.

(2) $BaSO_4$ stones can finish single crystal silicon to 1.5 nm Ra in 2 minutes under the condition that promotes chemical reactions.

Reference:

[1] Furushiro N, Higuchi M, Yamaguchi T, Sugimoto T, Matsumori N, Ogura H and Shimada S 2010 *Precision Engineering* **34** 419-424.