Four-body Finishing Method Using Hydrophilic Carrier Particles

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Abstract

Four-body polishing involves the use of polymer particles as abrasive-carrier particles, and it solves many of the problems from which conventional polishing suffers. However, because of the bubbling phenomenon, some problems still remain. To address these problems, we present the results of experiments that investigate the use of hydrophilic polymer particles as abrasive-carrier particles. We find that the use of polystyrene particles with a hydrophilic group attached to the surface results in a superior removal rate compared to the removal rate obtained when untreated polystyrene particles are used. In addition, the use of hydrophilic polyethylene particles treated by a surfactant to give a hydrophilic character results in a removal rate inferior to that of the removal rate obtained using untreated polyethylene particles. These results indicate that four-body finishing with hydrophilic carrier particles without surfactant improves the polishing characteristics over that of conventional polishing.

1 Introduction

Because of their elastic body, polishing pads are often used to polish glass and decrease scratches. However, polishing pads present numerous problems, such as the debasement of the edge geometry, waviness, frictional resistance to motion, and time-dependent deterioration of the polishing characteristics. To address these issues a technique called Four-body finishing, shown in Fig. 1, is proposed(1). Four-body finishing includes the addition of carrier particles into the slurry. Carrier particles are polymer particles ranging in sizes from about 1 to 10 μm. These particles work as micro-polishing pads in the processing area. Although four-body finishing addresses most of the difficulties of conventional polishing, common polymer particles cause a bubbling phenomenon in the slurry because they are hydrophobic in character. This phenomenon creates difficulties, such as making it difficult to set up the slurry and to

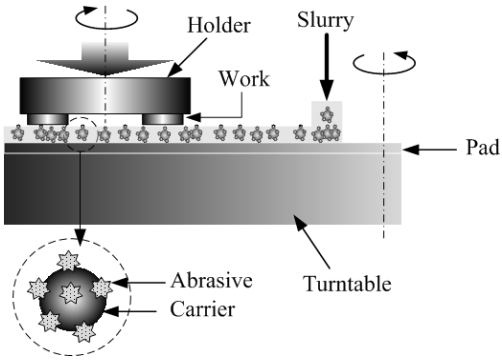

Figure 1: Schematic of four-body finishing technique

reduce carrier particles. To address these issues, we examine the use of hydrophilic polymers as carrier particles. In addition, we evaluate the finishing quality that results from the use of these particles in four-body finishing.

2 Four-body finishing with untreated polymer particles

For the polishing experiment, we observe the polishing characteristics that result from four-body finishing with different polymer particles. The polishing conditions remained identical for all experiments. The pre-polishing surface was prepared by lapping the GC#1000 abrasive, and the removal rate was calculated by measuring the weight of the work piece before and after polishing. The surface roughness and the edge geometry were measured by a three-dimensional surface profiler (Zygo New View 5032). Figure 2 shows the polishing characteristics resulting from four-body finishing with polystyrene particles and polyethylene particles. For all polymer particles used, the removal rate for four-body finishing decreases compared to the removal rate for conventional polishing. This result is attributed to the fact that carrier particles are hydrophobic in character, which prevents the abrasives from spreading in the regions of slurry bubble (which in turn can lead to a decrease in the removal rate). This result leads us to suggest that carrier particles are occasionally hydrophilic in character.

3 Four-body finishing with hydrophilic polymer particles

Here, we discuss the use of hydrophilic polymers in four-body finishing. H-PS particles are polystyrene particles onto whose surface hydrophilic groups by surface-graft polymerization are attached. H-PE particles are polyethylene particles that are rendered hydrophilic by treatment with a surfactant. We examine four-body finishing with each of these types of polymer particles. Figure 2 shows that the polishing characteristics of four-body finishing with H-PS particles are superior to those

attained with four-body finishing with polystyrene (PS) particles. In particular, the

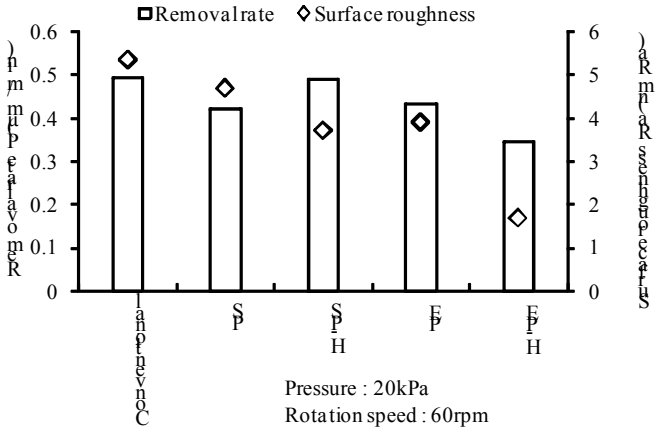

Figure 2: Polishing characteristics of four-body finishing

removal rate of four-body finishing with H-PS particles is similar to the removal rate of conventional polishing. However, the removal rate of four-body finishing with H-PE particles is less than the removal rate of four-body finishing with PE particles. However, the surface roughness resulting from four-body finishing with H-PE particles is superior to the surface roughness attained by other polishing techniques. These results clearly indicate that the use of hydrophilic carrier particles without a surfactant leads to an increased removal rate of four-body finishing compared to the removal rate of conventional polishing.

4 Dependence of relative removal rate on carrier particle concentration

To improve the removal rate of four-body finishing, we used polyurethane particles with nanosized silica particles attached to the surface, which serve to make the particles hydrophilic in character. Through a polishing experiment, we investigated the relative removal rate as a function of carrier particle concentration. Figure 3 shows the removal rate of four-body finishing normalized by the removal rate of conventional polishing. Upon increasing the rate at which PS particles are added to the slurry, the removal rate tends to decrease because significant bubbling occurs. However, upon increasing the rate at which polyurethane particles are added, the

removal rate exceeds the removal rate of conventional polishing. These results verify that four-body finishing provides polishing characteristics that are superior to those of

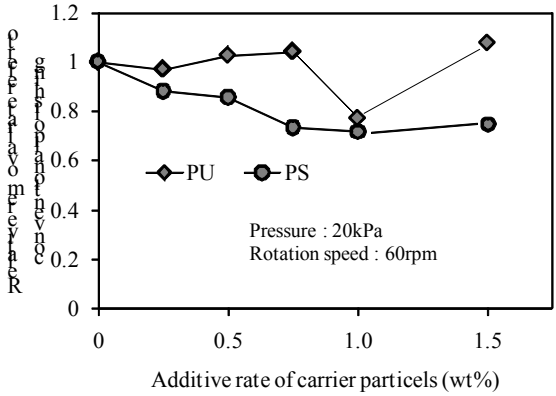

Figure 3: Change of relative removal rate with concentration of carrier particles

conventional polishing.

5 Conclusion

To address the difficulties involved in conventional polishing and to improve the polishing characteristics of four-body finishing, we examined four-body finishing using various carrier particles. The main results can be summarized as follows:

1. Four-body finishing resolves most problems of conventional polishing.
2. The bubbling phenomenon caused by hydrophobic carrier particles results in problems in the finishing process.
3. When hydrophilic carrier particles are used as the carrier particle, four-body finishing provides polishing characteristics that are superior to those of conventional polishing. The reason for this is that hydrophilic carrier particles decrease the bubbling phenomenon.
4. When polyurethane particles at 0.50 wt%, 0.75 wt% and 1.50 wt% are used, four-body finishing results in a higher removal rate than conventional polishing.

References:

[1] Yishen Lu, Yasuhiro Tani and Kenji Kawata, Proposal of Mirror Finishing Technology without Using a Polishing Pad(Development of 4-Body Finishing Technology Using Particles), *Trans. of the JSMEs, Series C*, Vol. 68, No.674 (2002), pp. 262-267.