Development of a urethane-containing epoxy resin polishing pad for glass finishing

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Abstract

Novel urethane-containing epoxy resin polishing pads with increased flexibility compared with epoxy resin pads were developed. The removal rate of the urethane-epoxy pad was higher than that of urethane pads and almost equivalent to an epoxy pad. The urethane-epoxy pad produced glass with a lower surface roughness than the epoxy pad. Furthermore, the waviness of the glass surface was markedly improved by polishing with urethane-epoxy pads.

1 Introduction

Cerium oxide (CeO_2) abrasives are widely used for glass surface polishing because a high removal rate and smooth glass surface can be obtained. However, the price of CeO_2 abrasives has rapidly increased because of the limited supply of rare-earth materials. As a result, technologies to reduce the use of rare-earth materials such as CeO_2 are strongly desired. We have developed a polishing pad that uses an epoxy resin as an alternative to a conventional urethane resin to reduce the use of CeO_2 abrasives [1]. It has been reported that epoxy resin polishing pads exhibit a removal rate more than 70% higher than that of a conventional urethane pad [1]. However, epoxy resin pads are more difficult to machine than urethane resin ones because epoxy resin is very brittle. In this paper, we describe a new urethane-containing epoxy resin pad that displays increased flexibility and polishing performance for glass compared with an epoxy resin pad.

2 Experimental setup

The urethane-epoxy resin pad was fabricated using the same process as that for an epoxy resin pad. First, curing and foaming agents were added to a mixture of

Table 1: Comparison of properties of polishing pads.

	Urethane	Epoxy-A	UE-A	Epoxy-B	UE-B
Urethane/epoxy ratio (wt%)	100/0	0/100	30/70	0/100	30/70
Porosity	0.4	0.4	0.4	0.6	0.6
Hardness	82	97	85	92	70

Figure 1: Photograph of urethane-epoxy pad

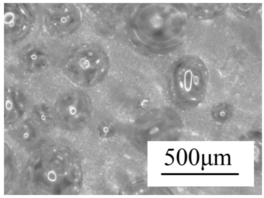

Figure 2: Surface image of a urethane epoxy pad

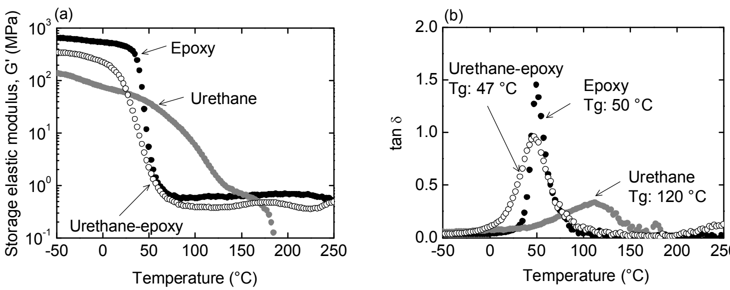

Figure 3: DMA properties of polishing pads. (a) Storage elastics modulus and (b) tan δ.

of prepolymer urethane and epoxy resin. The ratio of urethane and epoxy resin was 3:7 by weight. The mixture was heated to be cured at a controlled temperature. Finally, the resin was sliced to form polishing pads. The fabricated urethane-epoxy pad was evaluated by dynamic mechanical analysis (DMA). The polishing performance of soda-lime glass was investigated using the developed urethane-epoxy resin pad with CeO_2 abrasives under the conditions shown in Table 2. The polishing pad surfaces were treated using a diamond-electroplated conditioner with #100 grain size. The material removal rate was estimated from the weight loss of the glass. The surface roughness of the polished glass surface was evaluated using an optical interference profiler (Zygo, NewView5032).

3 Results and discussion

As shown in Fig. 1, the fabricated urethane-epoxy resin had a higher flexibility and smaller cutting resistance during the slicing process than the epoxy resin. Figure 2

Table 2: Polishing conditions

Polishing machine	Lapping machine NF-300, Nano Factor Co., Ltd
Substrate	Soda-lime glass, ϕ20 mm × t 10 mm, roughness 0.4 μm *R*a
Pressure	20 kPa
Work/Lap rotation	90 rpm/90 rpm
Polishing time	30 min
Abrasives	1.2 μm CeO_2 (SHOROX A-10, Showa Denko K.K.)
Concentration of slurry	3.0 wt% in deionized water
Supply rate of slurry	25 mL/min

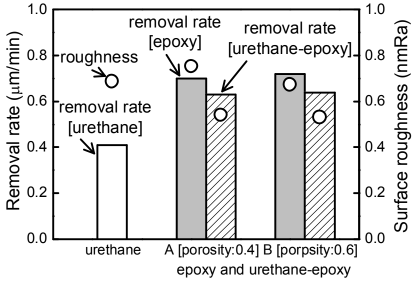

Figure 4: Comparison of the polishing performance of urethane, epoxy and urethane-epoxy pads

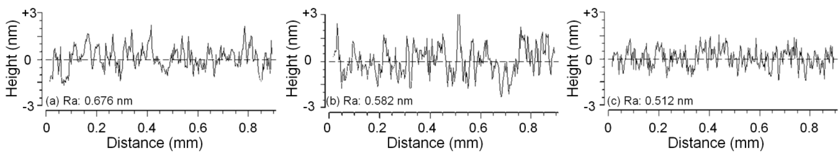

Figure 5: Surface profiles of glass polished using (a) urethane, (b) epoxy and (c) urethane-epoxy pads.

demonstrates that the urethane-epoxy pad contains many pores with a diameter of several hundred micrometres. The hardness of the urethane-epoxy pad was measured using a Type A durometer, and was found to be smaller than that of an epoxy resin pad with the same porosity, as summarized in Table 1. Figure 3 shows DMA characteristics of the polishing pads. The glass transition temperature (*T*g) of the urethane-epoxy pad was smaller than that of a conventional urethane pad and equivalent to that of an epoxy resin pad. However, the urethane–epoxy pad exhibited a smaller storage elastic modulus in the glassy region (below *T*g) than the epoxy pad. A comparison of polishing performance for glass is presented in Figure 4. Although the removal rate of glass using the urethane-epoxy pads decreased by approximately 10% compared with that using epoxy pads, it was still 60% higher than that using a conventional polyurethane pad. The urethane-epoxy pad produced a glass surface with a lower surface roughness *R*a (0.53 nm) than the conventional urethane (0.69 nm) and epoxy (0.67 nm) pads, as shown in Fig. 5.

As shown in Fig. 6, a lower power spectral density (PSD) can be obtained using the urethane-epoxy pad compared with the epoxy and urethane pads. Figure 7 shows that the arithmetic average waviness (Wa) of glass surfaces finished using urethane, epoxy and urethane-epoxy resin pads was 4.12, 1.84 and 1.01 nm, respectively. These results demonstrate that the waviness of a glass surface with a specific

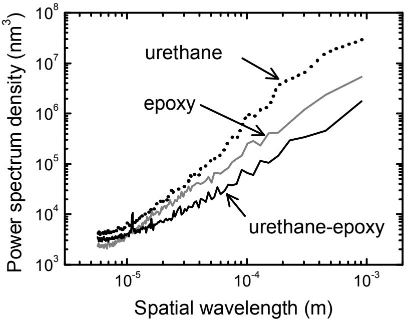

Figure 6: PSD spectra of the morphology of polished glass surfaces

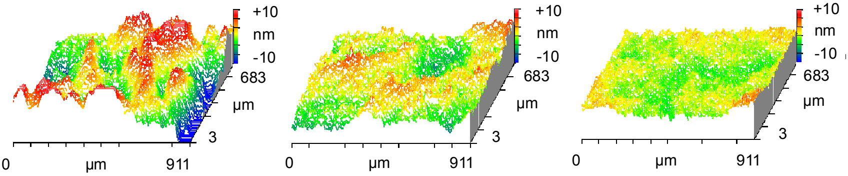

Figure 7: 3D optical profiler images of glass surfaces polished with (a) urethane (Wa: 4.12 nm), (b) epoxy (Wa: 1.84 nm) and (c) urethane-epoxy (Wa: 1.01 nm) polishing pads.

wavelength of several hundred micrometers was also improved by polishing with urethane-epoxy pads.

4 Conclusion

In this paper, the fabrication and the polishing performance of urethane-epoxy pads were reported. The urethane-epoxy pads showed improved flexibility compared with epoxy pads. The waviness of glass surfaces was markedly improved by polishing with urethane-epoxy pads.

5 Acknowledgement

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Reference:

[1] J. Murata, Y. Tani, M. Yamada, T. Yanagihara, N. Nomura, R. Hirokawa, Y. Zhang, O. Kirino, Proc of 11th Int. Conf. of euspen (2011) vol. 2, pp. 136-139.