MICRO MOLDING OF METALLIC GLASS STRUCTURED COMPONENTS

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INTRODUCTIONS

Recently, more miniaturization and higher integration are required in the LSI circuits to be installed in the mobile devices like cellular phones and PDAs. Therefore the pitch of electrode pads on the LSI circuits has become narrower. In the manufacturing process of LSI circuits, IC probes contact with the pads to check the electric property as shown in figure 1. Their size and pitch are similarly required to be small. The material of the IC probe should have electric conductivity, a high elastic limit, and should be able to be manufactured into 3D microstructures. However, the crystal grain size of conventional materials is too large to realize the micron order pitch. In this experiment, a new method for press molding of metallic glass that satisfies these requirements is proposed. In this method, the shape of probe is created with press molding of the metallic glass, and the unnecessary part of the molded component is removed by machining.

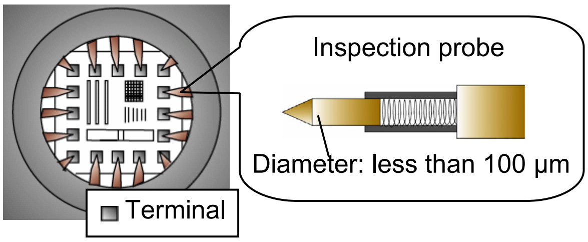


FIGURE 1. Wafer inspection

CHARACTERISTICS OF METALLIC GLASS

The metallic glass is a material with an amorphous structure without regular atom arrangement. Therefore, it is a material having excellent character for the spring material with high strength and high elasticity limit. Moreover, the size effect of metallic glass is small because it is an isotropic and a homogeneous material. In addition, it has the super-plasticity in the temperature region called super-cooled liquid state and returns to amorphous structure after cooling. Figure 2 is a transformation diagram of metallic glass. Accordingly, these characters enable producing the micro structured components.

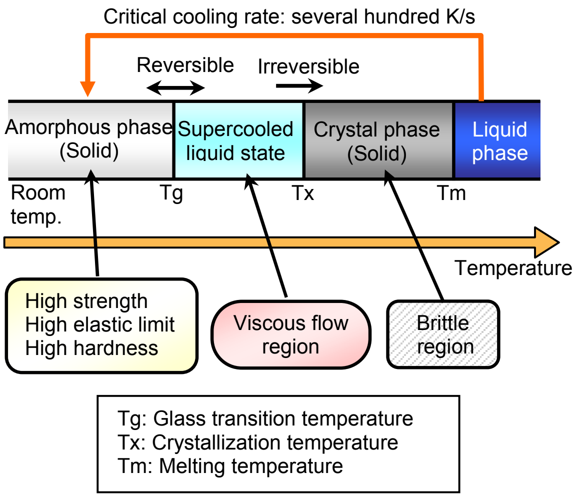


FIGURE 2. Transformation diagram of metallic glass

EXPERIMENTAL SETUP

In this study, Zr based metallic glass; $Zr_{55}Cu_{30}Al_{10}Ni_{5}$ (atomic %) was molded. The Zr based metallic glass is suitable for molding process, because its super-cooled liquid state is wider than that of other materials. Tungsten carbide was used for mold material polished. Three types of micro grooves as shown in figure 3 were ground on mold at 100 μm pitch. The simultaneous 4-axes controlled grinding machine (ULG-100D (H3), Toshiba Machine) was used for grinding. Figure 4 shows a view of the high precision glass-molding machine (GMP-311V-SS, Toshiba Machine), which was used for the experiments. This machine is mainly composed of a chamber covered with a silica tube, a heating unit using infrared lamps, and driving shafts that move the lower mold up and down. A schematic illustration of one cycle of the press molding is shown in figure 5. At first, nitrogen gas is filled in the chamber and metallic glass is heated to the molding temperature. Next, the molds are driven to the pressing position and metallic glass is pressed during molding time. At last, metallic glass and molds are cooled with flowing nitrogen gas and the molded component is ejected. Molding conditions are shown in table 1. In this paper, a metallic glass was pressed on different molding temperatures and at different molding time to investigate the influence on the transcription.

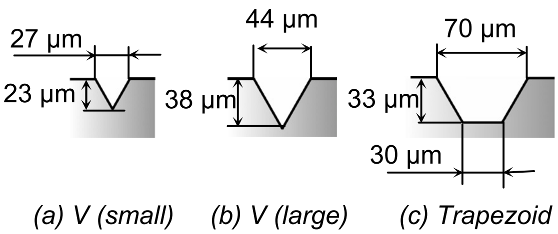


FIGURE 3. Shape of grooves

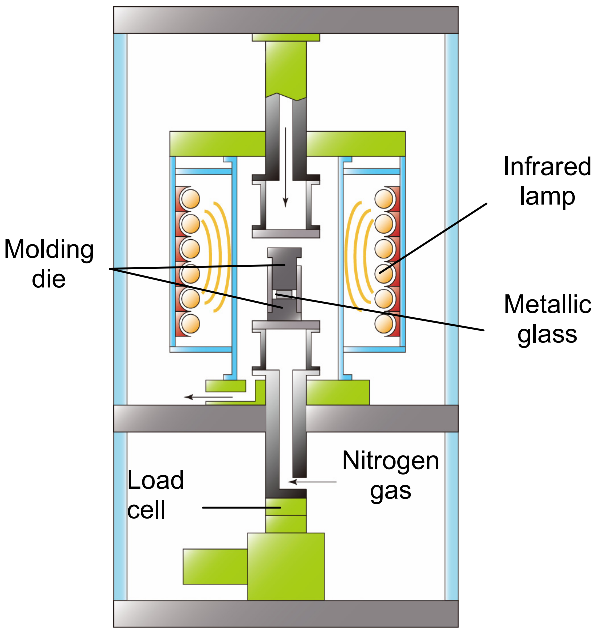


FIGURE 4. Schematic illustration of metallic glass molding machine

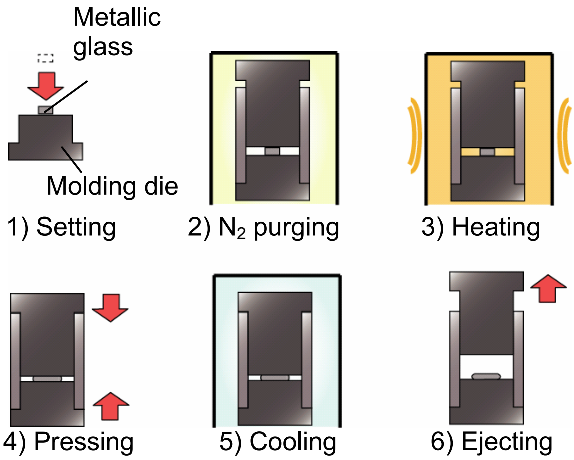


FIGURE 5. Molding process

TABLE 1. Molding conditions

Molding material Size Tg Tx ΔT (Tx-Tg)	Zr based metallic glass Φ3 mm×0.55 mm 418 °C 504 °C 86 °C
Mold material	Tungsten carbide
Molding temperature	430-460 °C
Molding load	1, 1.5 kN
Molding time	30-120 s

EXPERIMENTAL RESULTS

Three types of microstructures shown in figure 6 were molded. Figure 7 is scanning electron microscope image of molded metallic glass components. It was confirmed that micro groove of molding die were well transcribed the molded components, V (large), V (small), Trapezoid. The molded shapes are measured with a non-contact measuring system (NH-3SP, Mitaka Kohki) and the deviation of molded component as shown in figure 8 was evaluated in order to discuss the performance of transcription. Figure 9 shows effects of molding temperature on molding deviations with different shape of groove. Because the viscosity of metallic glass decreases at high temperature, the deviation became smaller as the temperature becomes higher. At 440 °C, little deviation remained in case of V-shaped molding while there was no deviation of trapezoidal molding. Therefore, the transcription rate of trapezoidal groove is higher than that of V-shaped groove. Next, figure 10 shows effects of molding time on molding deviation. The deviation of V-shaped groove was decrease as molding time longer, however there were deviations in all conditions. There was very little deviation of trapezoidal groove in all conditions, however the edges of molded workpiece were rounded when molding time is shorter. It is necessary to mold with enough time to transcribe microstructure precisely.

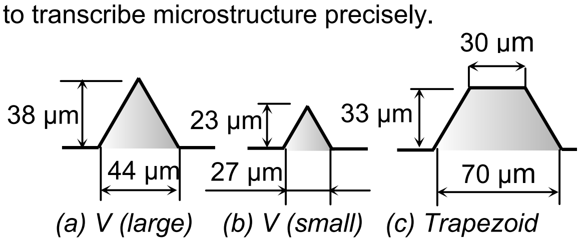


FIGURE 6. Shape of molded components

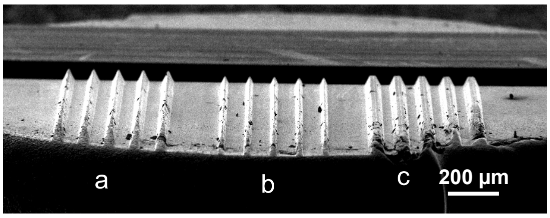


FIGURE 7. SEM image of molded components

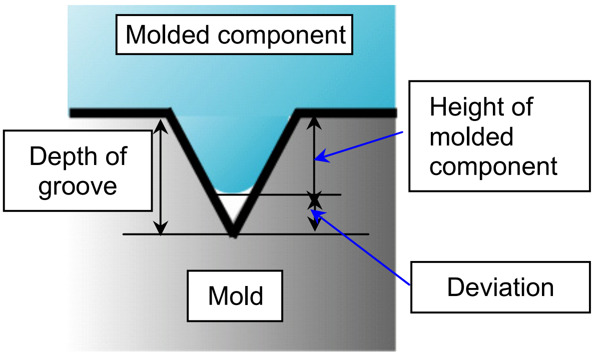


FIGURE 8. Definition of molding deviation

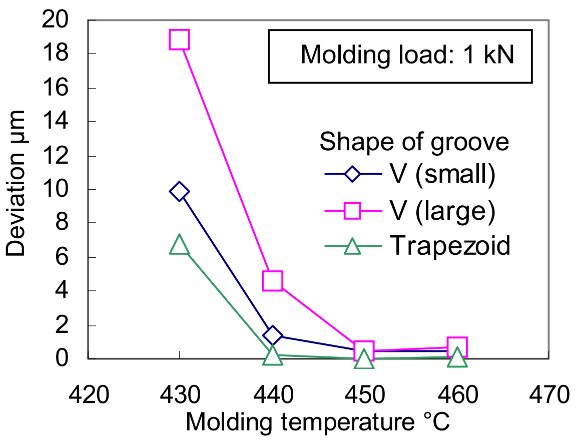


FIGURE 9. Effects of molding temperature on molding deviations

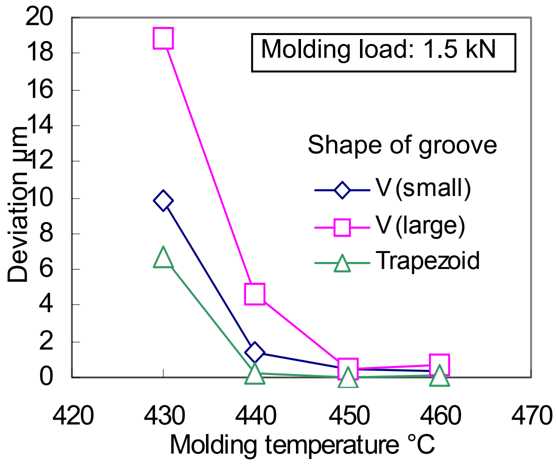


FIGURE 10. Effects of molding time on molding deviations

REMOVING UNNECESSARY PART OF MOLDED COMPONENT

The molded component includes unnecessary parts, so removing process is needed to obtain a probe as shown in figure 11. In this paper, the unnecessary part was removed with grinding using a micro diamond wheel. The high precision vertical grinding machine (UVM-350B, Toshiba Machine) was used for removing process. A schematic illustration of grinding process is shown in figure 12. The molded component was fixed on the jig with heat-resistant and impact-resistant adhesive. Grinding conditions are shown in table 2. SEM images of probe manufactured are shown in figure 13. The width of probes is less than 100 µm and their pitch is 100µm. Micro probes made of metallic glass with narrow pitch were obtained by molding and grinding process.

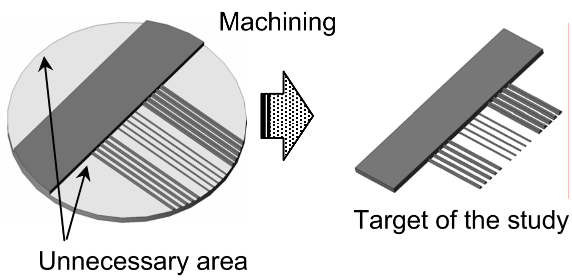


FIGURE 11. Manufacturing process of micro probes

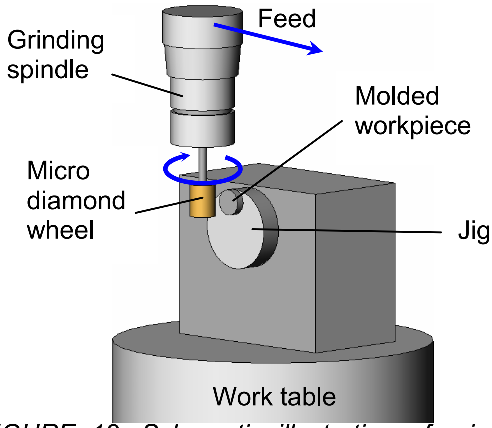


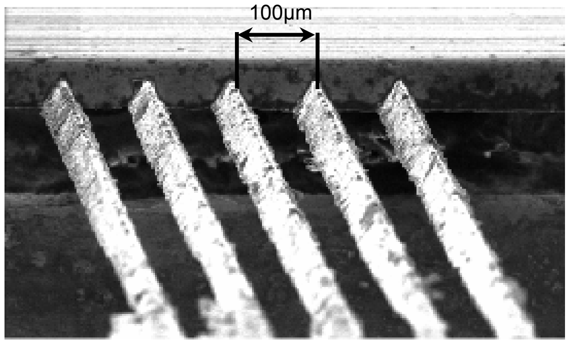
FIGURE 12. Schematic illustration of grinding process

TABLE 2. Grinding conditions

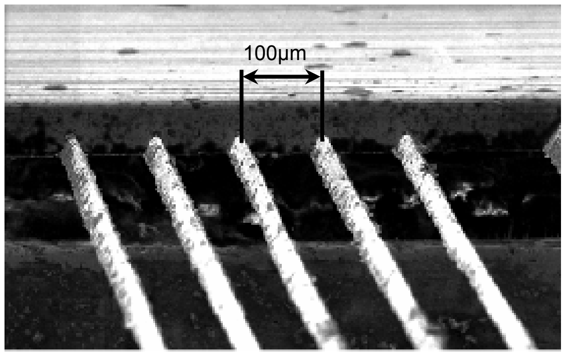
Grinding wheel Grain size Diameter Rotational rate	Resinoid bonded diamond #400 Φ10 mm 2×10^4 min^{-1}
Depth of cut	5 μm/pass
Feed rate	2 mm/min
Coolant	Solution type

CONCLUSIONS

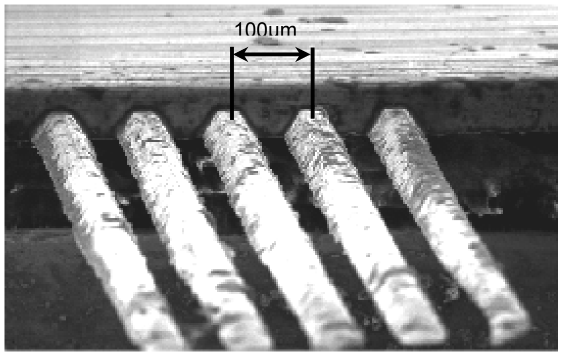
In this research, a metallic glass molding experiment was carried out at various temperatures and molding time. As a result, successful transcription of microstructure on metallic glass was confirmed. The transcript rate was increased with increasing temperature and molding time. The transcription rate of trapezoidal probe was better than that of V-shaped probe. The final micro probe was obtained by removing unnecessary parts by grinding.



(a) V-shape (large)



(b) V-shape (small)



(c) Trapezoid

FIGURE 13. SEM images of micro probes

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