Groove Distortion Analysis of Pregrooved Substrates Manufactured By 2P Process

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Grooved optical disk trackability is strongly dependent on groove quality, and more especially, on groove distortions. [1] Analytical results of groove distortions in a pregrooved substrate manufactured under various 2P (photopolymer) process conditions are presented in this paper.

Grooves were replicated on various shaped PMMA plates using the 2P process. The stamper was circular, as schematically shown in Fig. 1. The amount of head displacement was measured using an LED, a mirror attached to the head, and a PIN photodiode to determine groove shape. When distortions exist in the groove, the optical head compensates for decentering. Differential output power from the split PIN photodiode is proportional to the amount of head displacement. Ordinarily, the differential output power signal (position signal) is a sine-wave with amplitude proportional to the deviation of the pregroove center from the rotation center. By employing Fourier analysis, higher order distortion amplitude was estimated. In these experiments, disk decenter amplitude was 20-25 μm (30 Hz).

Position signal waveform and frequency spectrum at a radius of 50 mm in a substrate pregrooved from a 23 cm square plate is shown in Fig. 2-(a). When no groove distortions exist, the position signal waveform is a sine-wave. However, Fig. 2-(a) shows a curve distinctly different from a sine-wave. In addition, the position signal spectrum shows large distortion in the fourth harmonic frequency. Distortion amplitude at a radius of 50 mm is about 1 μm . That of the outer grooves is larger than that of the inner grooves and is about 10 μm at a radius of 90 mm. Furthermore, distorted groove shape is similar to that of a spool. As schematically shown in Fig. 1, the grooves expand in the 45° direction, while the grooves are depressed in the X and Y direction. Position signal waveform and position spectrum of a pregrooved substrate manufactured using a circular PMMA plate is shown in Fig. 2-(b). Pregroove distortion amplitude replicated on the circular PMMA is smaller than that on square plates.

To clarify the dependence of groove distortion on PMMA plate shape, thermal stress magnitude was calculated during the 2P process using a fine element method. PMMA plate temperature resting on the circular stamper was raised to about 50 °C to obtain good 2P resin liquidity. Outside of the stamper, PMMA plate temperature was still around 20 °C (Fig. 1). At the boundary, thermal stress proportional to the temperature difference is caused. On the calculation, the thermal stress magnitude is 10⁶ N/m² at a 90 mm radius in the 45° direction on a square PMMA plate. Thus, plate expansion in the 45° direction

is suppressed. Expansion amount decreases compared to the X and Y direction during the process. When thermal stress magnitude is 10^6 N/m^2 , groove distortion amplitude at a 90 mm radius is about $15 \mu\text{m}$, nearly equal to the experimental result. In addition, groove distortion amplitude decreases with radius decrease. When substrates shrink at room temperature, grooves in the 45° direction are further away from the center than those in the X and Y direction. That is, the grooves expand in the 45° direction, and are depressed in the X and Y direction. (as shown in Fig. 1)

It was concluded that groove distortions were caused by thermal stress during the 2P process.

1 A. Iwasawa, H. Yamazaki, S. Fujimori and N. Funakoshi, Proc. SPIE., 695 (1986) 86

Figure 1 Position of PMMA plate on stamper and simulated shape of distorted groove.

Figure 2 Position signal waveform (left) and frequency spectrum (right) from a pregrooved substrate manufactured using a square PMMA plate (a) and a circular PMMA plate (b).