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Domain Wall Displacement Detection Mini Disc with Land/Groove Recording Applied to Mini Disc Systems

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Abstract:

We confirmed a wide tolerance and capability of over 2.0 GB/64 mmφ, equivalent to 14 times the capacity of Mini Disc (MD) using a combination of domain wall displacement detection (DWDD) and land/groove recording and by optimizing groove geometry and surface treatment.

Keywords:

MO, DWDD, land/groove, groove geometry, tolerance, MD

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1. Introduction

The use of optical disks in homes has been increasing as a distribution and preservation medium for music and images, year by year. In particular, compact disc (CD), DVD and MD are recognized as platforms whose interchangeability is popular among users. MD has the characteristic that the player itself is portable because of its small size, and it is commonly being used in Japan by many young people to listen to music outside the home. As the network society expands dramatically through on-line systems, these media can be expected to serve as a format through which each individual can manage information off-line if necessary. Thus, larger capacity MDs can be expected to be developed with the added function of storing not only music but also network data.

DWDD MO is the most useful media for achieving highly linear density without the use of shorter wavelengths and higher numerical aperture (NA) objective lenses. We investigated DWDD MO with land/groove recording, which is effective for higher track density, as applied to an MD system. Optimizing groove geometry and the surface condition of the substrate, a wide tolerance has been obtained at a capacity of over 2.0 GB/64 mmφ, equivalent to 14 times the capacity of MD, using the same dimension optical pick-up as the MD system.

2. Model of DWDD in Land/Groove Recording

In the original model [1] of DWDD, nonmagnetic treatment with local heating produces unclosed magnetic domain walls only at the leading edge and the trailing edge. These domain walls move to the highest temperature position in the readout beam by the driving force from the temperature gradient. Because the total area of each domain wall remains constant during wall movement, the domain can expand smoothly and we can obtain a signal irrespective of the resolution of optical pickup.

Figure 1 shows the cross section of a film with the land/groove substrate with a deep groove of 185 nm. It was confirmed that the film deposition is discontinuous at the boundary between groove and slope, as shown by the white arrow in Fig. 1. We believe that deeper [2] grooves cause this discontinuity of film deposition and the change of magnetic characteristics at the slope, which has the same effect as the nonmagnetic treatment.

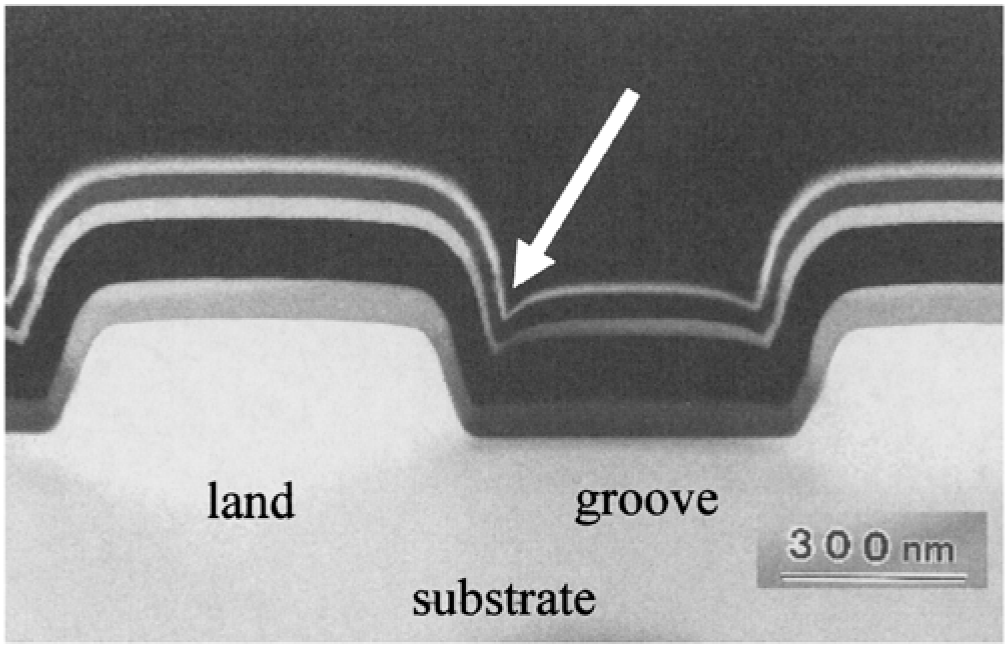

Fig.1 : Cross section of disk.

Table.1 : Experimental conditions.

Wavelength	660 nm
N.A.	0.52
Substrate	1.2 mm
Recording	Pulse strobe MFM
Encoding	(1, 7) RLL
Decoding	PR (1, -1) +Viterbi
Clock	18 MHz
Linear velocity	1.1-2.2 m/s

Because of the effect of the discontinuity at the boundary between groove and slope, it is believed that the wall on the land track will move together with that on the adjacent slope areas, while the wall in the groove remains independent. The surface roughness on slopes causes a resistance force against wall movements particularly on land. Therefore, it can be concluded that controlling [3] the surface roughness on slopes is very important for land/groove recording of DWDD.

3. Experiment

Table 1 shows the experimental conditions for this report. We prepared the substrates with groove depths of 140 to 200 nm and track pitches of 0.50 to 0.65 µm. The magneto-optical layer is an exchange coupled film, consisting of, in order, a displacement layer, switching layer, and recording layer. The thickness and composition of each layer were optimized to obtain good signal to noise ratio (SNR). These recording films were sandwiched between SiN films, with a UV resin film coated on the end.

The readout pick-up had the same optical condition as that of MD-DATA2 [4], i.e., an objective lens of 660 nm and N.A. 0.52 which has to satisfy the demand of compatibility with conventional MDs, except for the optical phase compensation with both land and groove. We adopted the recording method of laser strobe magnetic field modulation and data coding of (1, 7) RLL. Data detection was performed by PR (1, -1) +Viterbi using the signal equalized [2] to PR(1, -1) of MO read-out.

4. Results

4.1. Substrate surface treatment

We adopted a pretreatment of exposure at 0.4 J/cm^2 by 260 nm UV irradiation or annealing for 2 h at 125°C on PC substrates. The conditions of pretreatment were optimized from the point of view of bottom jitter and write power margin.

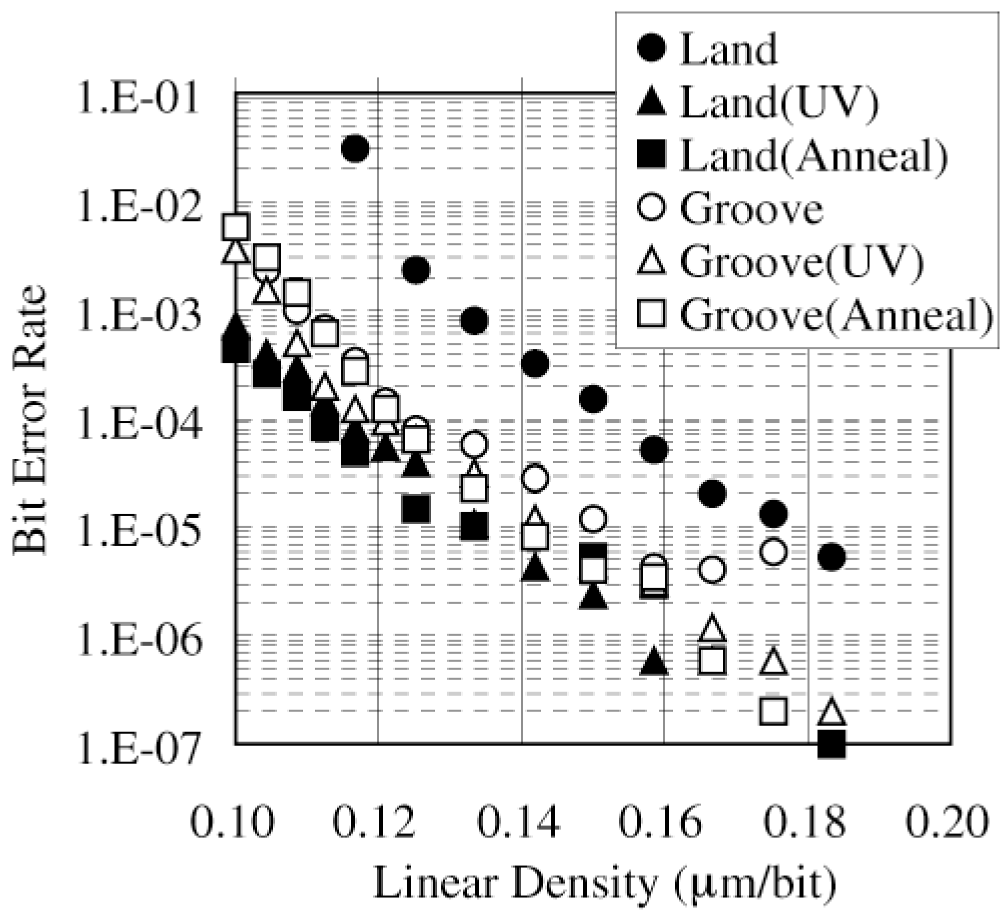

Fig.2 : Bit Error Rate dependence on linear density.

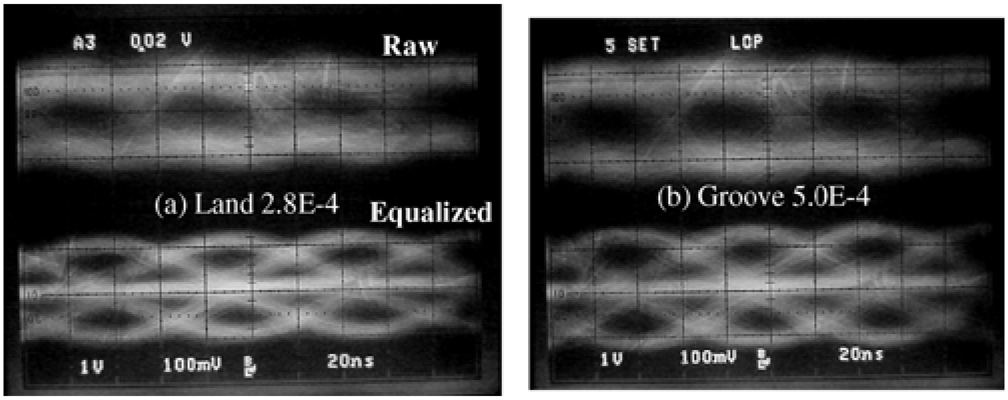

Fig.3 : Eye pattern at 0.108 µm/bit.

Figure 2 shows the dependence of bit error rate on the linear density of the disks with groove depths of 185 nm and track pitches of 0.60 µm. The signal characteristic on land was remarkably improved by the pretreatment. The limitation of linear density decided by the criterion of bit error rate 5E-4 was improved from 0.14 µm/bit to 0.10 µm/bit. Figure 3 shows eye patterns for land and groove at 0.108 µm/bit, equivalent to about 10 Gbit/inch^2, at which both tracks surpass the error criterion.

From an atomic force microscopy (AFM) measurement, as shown in Fig. 4, the pretreatment reduced surface roughness particularly on slopes. It was confirmed that the decrease in surface roughness on the slopes of grooves retrieved the magnetic wall mobility on the land track.

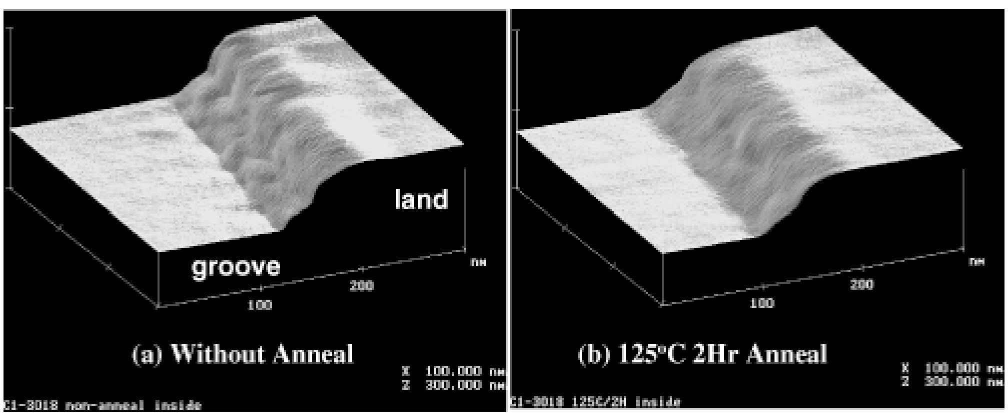

Fig.4 : AFM images of PC substrate.

4.2. Groove geometry

We measured the dependence of bottom jitter at 0.15 µm/bit on groove geometry, using a Glass2P substrate that was faithful to the mother stamper. We tested several geometric parameters for the substrates, groove depths of 140, 165 and 190 nm, track pitches of 0.50, 0.55 and 0.60 µm and groove duty from 40 to 60%.

Figure 5 indicates the correlation of bottom jitter with the aspect ratio of groove depth (D) to groove width (W_g) which excludes the sloped areas. The bottom jitter depends on the groove aspect ratio of D/W_g, and the optimum aspect ratio was about 0.40 at a groove depth of 190 nm. We consider that a step and bottom coverage of film deposition depends on the aspect ratio of the groove and that coverage affects the discontinuity of the film.

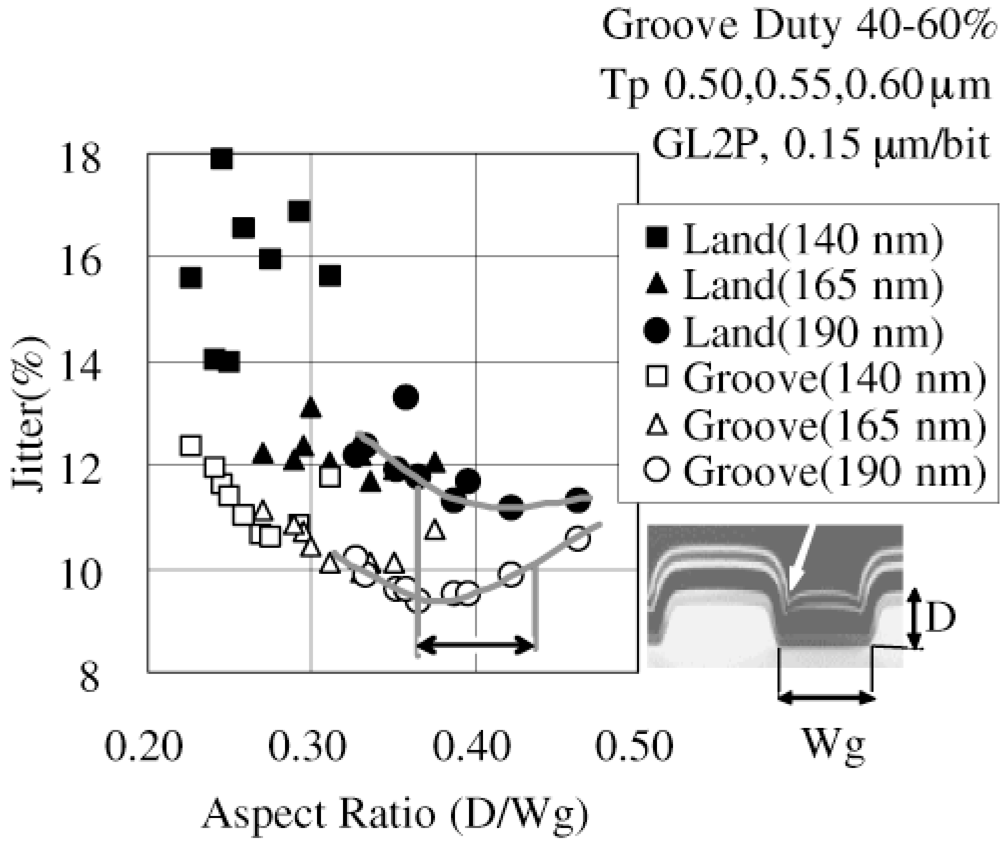

Fig.5 : Jitter dependence on groove geometry.

Regarding the power margin of DWDD, it is understood that it is sensitive to the depth rather than track pitch, as shown in Fig. 6. The results show that the groove geometry is a very important parameter for not only bottom jitter but also margin characteristics in DWDD.

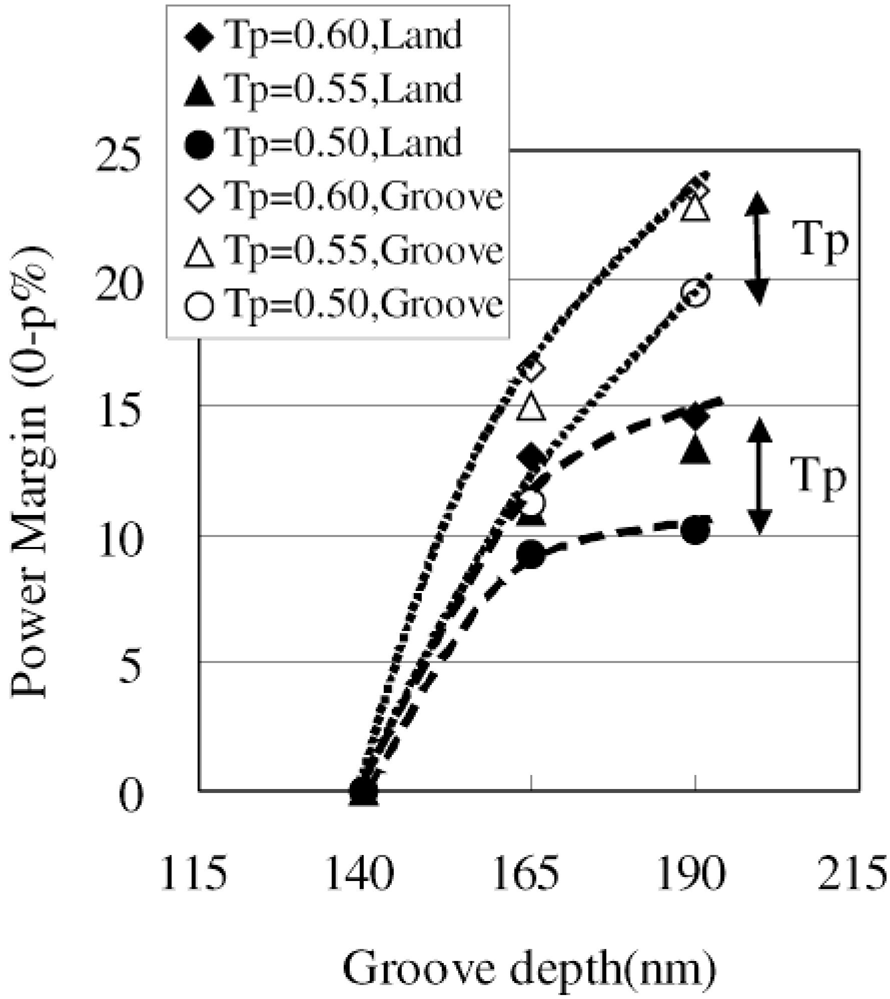

Fig.6 : Power margin dependence on groove depth and track pitches.

4.3. Molding process

A transcription defect can occur in a PC substrate with a deep groove during the molding process. It can be assumed that deformation of land corners of the substrate occurs due to friction with the metal stamper at release because of the difference between the temperature expansion coefficients of the PC plastic and metal stamper.

Figure 7 shows the jitter dependence on the height of the horn at land corners of substrates of 190 nm groove depth under various conditions of UV exposure. The deformation of land corners could be suppressed by optimizing the conditions of molding and pretreatment. We believe that the horn deformation affects magnetic wall movement similarly to the surface roughness of slopes.

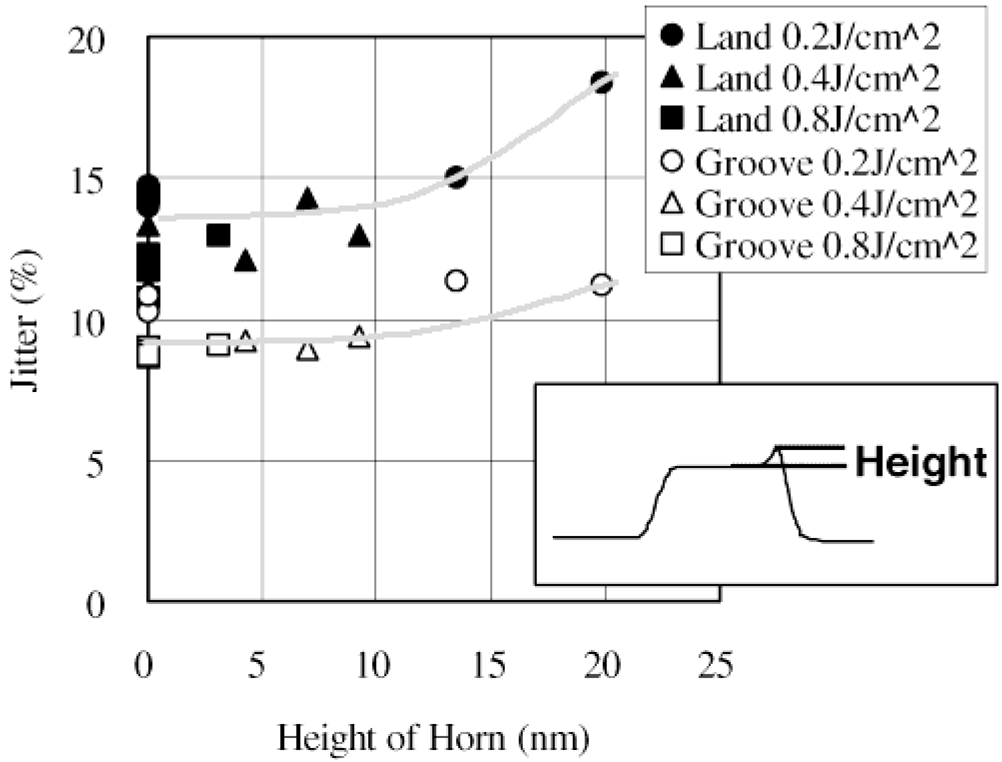

Fig.7 : Jitter dependence on horn height.

4.4. Tolerance

We estimated the tolerance characteristics of the disk under optimum conditions for groove geometry, surface treatment and mold condition. In order to select appropriate linear density for measuring system margin, we first measured the power margin dependence on the linear density, as shown in Fig. 8. We defined the power margin with land and groove recording as follows. In the case of power margin for land, the lower limit is determined as an overwriting power when the bit error rate is less than 5E-4 and the upper limit is determined as a power of writing both adjacent land tracks when the bit error rate on the groove between these is less than 5E-4. In the case of a groove, the definition is the reverse.

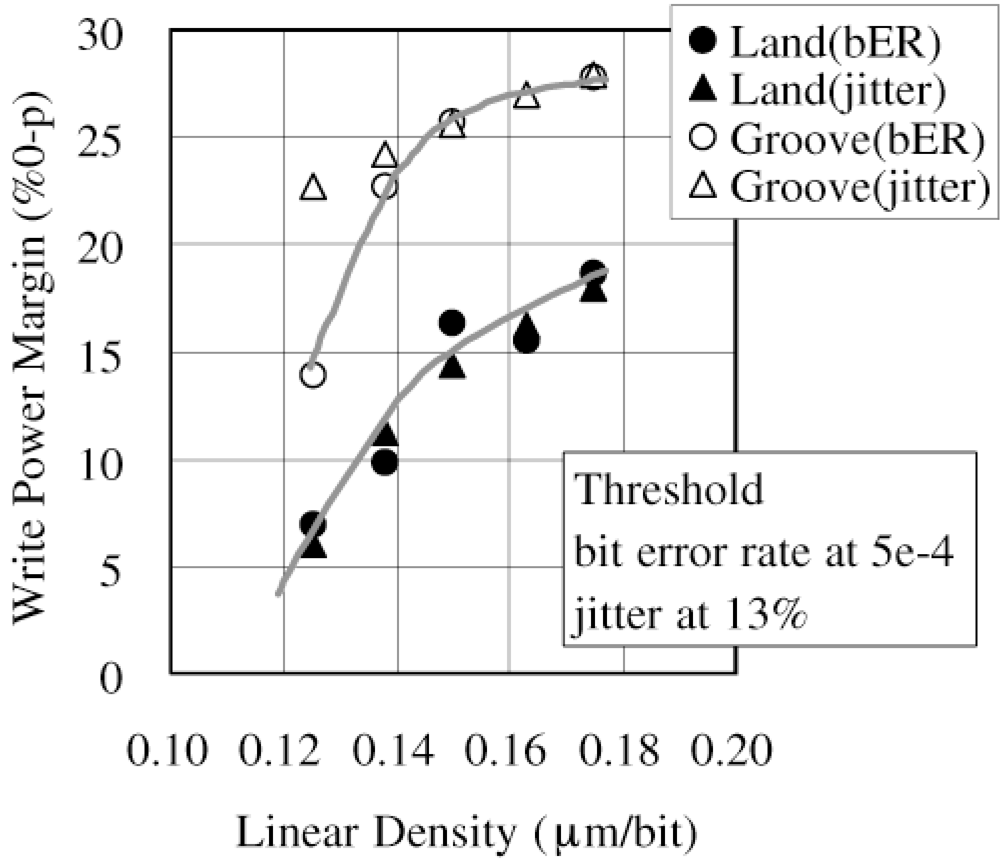

Fig.8 : Power margin on dependence on linear density.

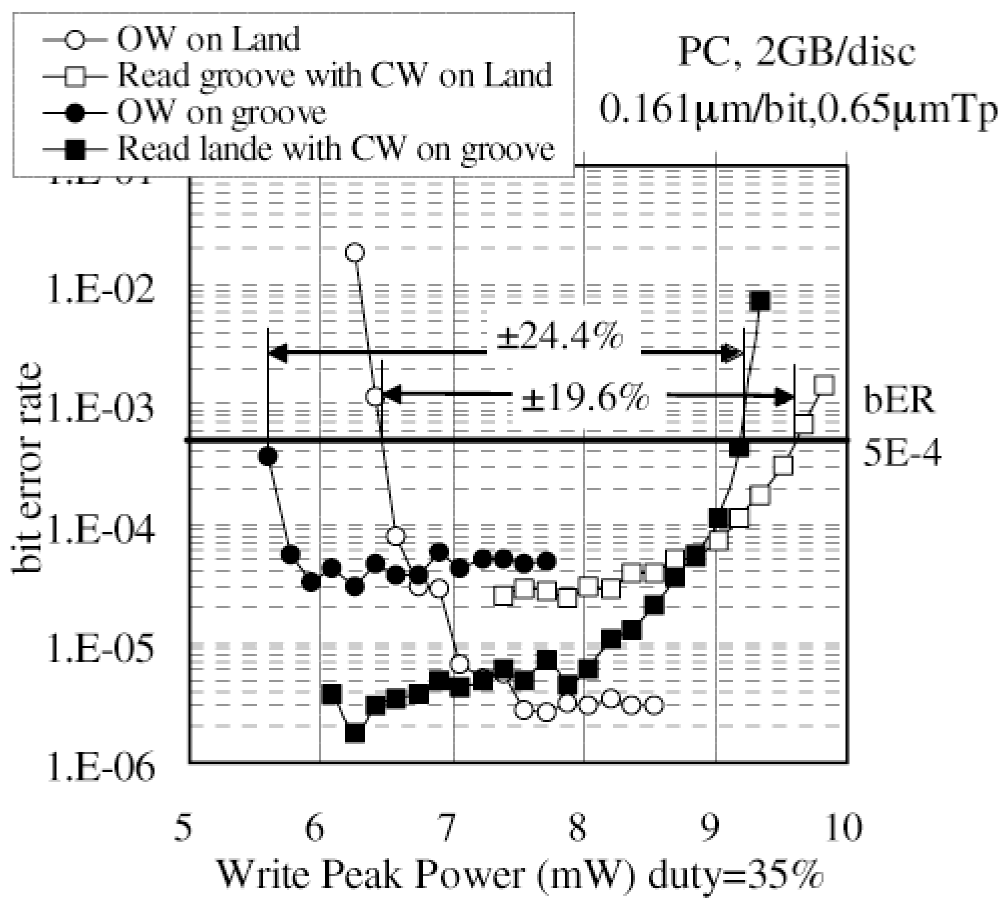

Fig.9 : Write power margin at 2 GB/disc.

A disk with 180 nm groove depth has an available linear density above 0.15 μm/bit to secure a sufficient power margin of ± 15% at a track pitch of 0.60 µm, which is equivalent to 7.2 Gbit/inch^2 or 2.3 GB/disc. From the point of view of acquiring robustness, we set the density at 0.161 µm/bit and 0.65 µm Tp, corresponding to a 2.0 GB/disc, and measured several parameters for a disk with 200 nm groove depth.

The value of the wide write power margin with land (± 19.6%) and groove (± 24.4%) could be obtained from the disk, when using a recording magnetic field of 250 Oe, as shown in Fig. 9. Table 2 indicates the tolerance of several parameters necessary to achieve a write power margin of ± 10%.

Table.2 : Tolerance.
(write power margin>± 10%)

Radial tilt (deg)	± 0.60
Tangential tilt (deg)	± 0.60
Defocus (µm)	>± 1.5
Off track (nm)	± 50

In Fig. 10, it was confirmed that the DWDD movement occurred stably at temperatures up to 71°C.

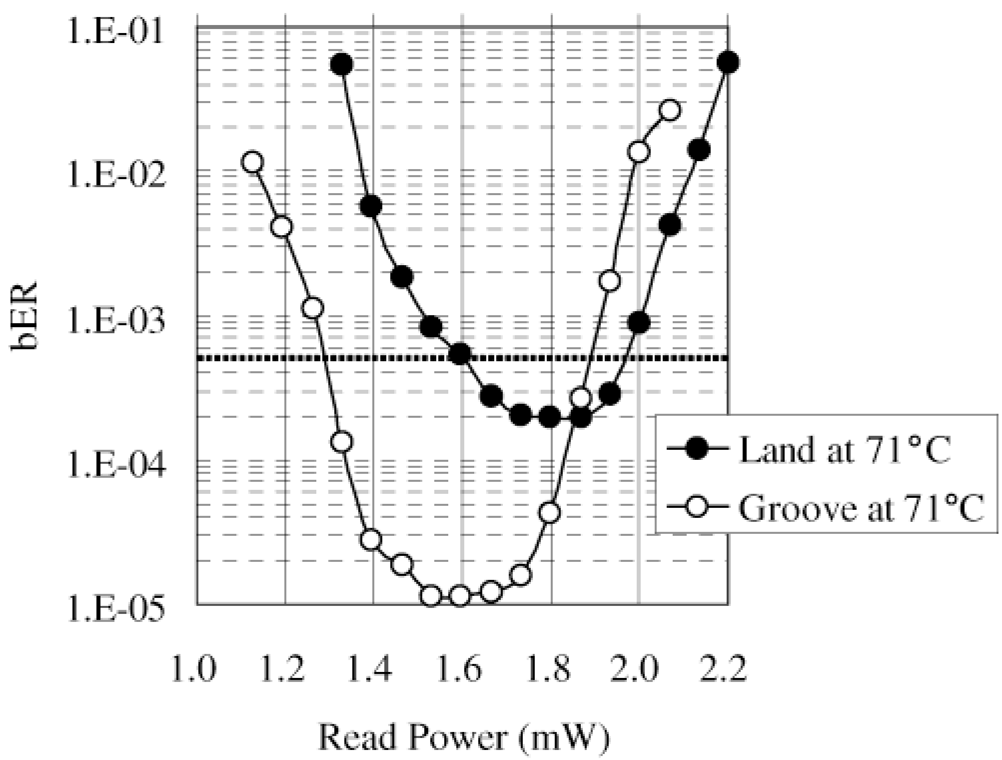

Fig.10 : Read power margin at 71°C.

These results prove that the disk meets the demands of the MD system.

5. Summary

It has become clear that groove geometry, surface roughness and land corner shape are related to the mechanism of DWDD with land/groove recording.

Optimizing groove geometry, surface treatment and molding conditions, a wide tolerance and capability of over 2.0 GB/64 mmφ, equivalent to 14 times the capacity of MD, was confirmed.

This can be accomplished by using the same dimension optical pick-up of the MD system to maintain the interchangeability of the MDs.

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