High-speed DVD-RAM disk with a wide range of recording speed

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Abstract

16x-speed DVD-RAM disk has been developed. In order to realize high-speed overwrite over a wide range of speed between 6x (i.e. 24.6m/s linear velocity) and 16x (65.6m/s), we have adopted a new phase-change film based on Ge-Bi-Te ternary alloy, a rapid cooling layer structure, and a new write strategy of castle type. The obtained disk has satisfied all of the specification of DVD-RAM version 2.0 standards. Here, we discuss the relations between recording conditions and laser heating durations for the wide range of speed based on computer simulation results.

Key words: phase-change materials, recording speed, crystallization, DVD-RAM, computer simulation

1. Introduction

High-speed recording performance has been always one of the main targets in the field of phase-change rewritable optical disks. This performance gives a great deal of merits to users. For instance, ones can record high-definition video with high-transfer rate, and ones can back a large amount of data up in a short time. It is natural that there becomes greater demand for high-speed recording as the amount of information to be recorded on a disk increases.

To meet the demand, we have ever commercialized 2x, 3x and 5x-speed DVD-RAM disks, having the feature of high accessibility and superior cycle-ability. 16x-speed DVD-RAM is the newest version of DVD-RAM disk that we have developed. When the disk is operated at the maximum speed of 16x, the linear velocity of the disk reaches as high as 65.6m/s. As the relative velocity between a disk and a laser spot becomes faster, the possible laser heating duration passing a point of the disk becomes inevitably shorter. For example, 16x speed corresponds to achieving both of crystallization and amorphization by the very short laser irradiations of less than 10 nanoseconds.

One important additional requirement is that the 16x-speed DVD-RAM disk has to respond to the operation over the wide range of speed since it is utilized in Constant Angular Velocity (CAV) mode. It means that the16x-speed DVD-RAM specifications prescribe that the disk shall be recorded at a speed of between 6x and 16x. In other words, the maximum recording speed is 2.67 times faster than the minimum recording speed.

This paper has two objectives. One is to discuss conditions for designing 16x-speed DVD-RAM disk. The other is to report results of recording characteristics of the developed 16x-speed DVD-RAM disk.

2. Background Conditions for Designing 16x-speed DVD-RAM Disk

Specifications of 16x-speed DVD-RAM disk are shown in Table 1. Recording speed of the disk ranges from 6x (24.6m/s) to 16x speed (65.6m/s). In CAV mode operation, 6x-speed recording is performed on the most inner side of the disk, whereas 16x speed recording is performed on the most outer side.

Table 1. Specifications of 16x-speed DVD-RAM disk

Wavelength	660nm
N.A. of objective lens	0.6
Minimum mark length	0.42μm
Track pitch	0.615μm (Land & Groove)
Modulation method	(8-16) modulation code
Linear velocity	24.6m/s (6x) - 65.6m/s (16x)
User data transfer rate	66Mbps (6x) - 177Mbps (16x)
Channel bit rate	175Mbps (6x) - 467Mbps (16x)

Consider firstly the linear velocity. From the view of a certain point on the revolving disk, the laser spot passes through the point while heating the recording material of the disk. That is, the duration of laser heating t_d is defined as $t_d = w / v$, where w denotes the size of the laser spot (FWHM) and v denotes the linear velocity [1].

Figure 1 shows the relation between t_d and v when w takes as 0.61 μm, typical laser spot size for DVD system. The laser heating duration t_d is inversely proportional to the recording speed. We see from the figure that t_d equals to 25ns for 6x speed (24.6m/s), and reduces to only 9ns for 16x speed (65.6m/s).

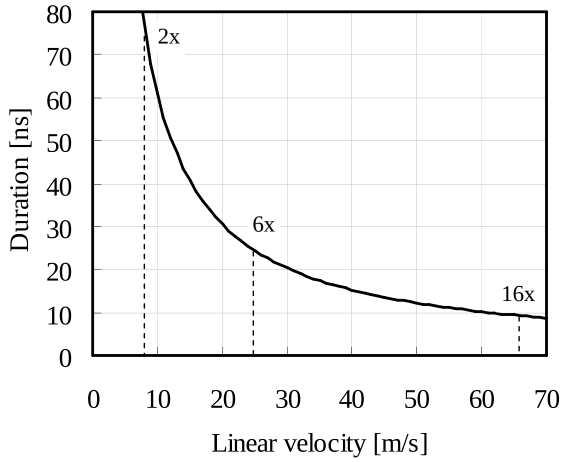


Fig. 1. Calculated result showing the relation between linear velocity and laser heating duration. The laser spot size is 0.61 μm.

Write strategy, waveform of laser pulses for forming amorphous marks, also should be taken into consideration. Shown in Fig. 2 (a) is the write strategy, which is utilized for the conventional 5x DVD-RAM disk. With this write strategy, laser power is modulated between peak power P_p and bias power P_{b1} in a period of channel clock T. In the case of multi-pulse type, the cooling rate in the amorphizing process can be changed by selecting the pulse width m of multi-pulses and the bottom level between multi-pulses P_{b2}. The controllability indeed gave an advantage to expand the range of recording speed. However, we could not adopt the multi-pulse strategy for the 16x-speed DVD-RAM. This is because that the channel clock T is shortened to 2.14ns at 16x recording speed, and it becomes practically difficult to make such a short multi-pulses corresponding to the short channel clock; the required switching time of laser modulation reduces to less than 1ns.

Thus, the castle-type write strategy, shown in Fig. 2 (b), was applied for the 16x-speed DVD-RAM. Here, the front part and the rear part of the pulse stick out from the center. With this write strategy, the laser power can be modulated with the channel clock of 2.14ns, while the degree of the controllability decreases compared to multi-pulse type.

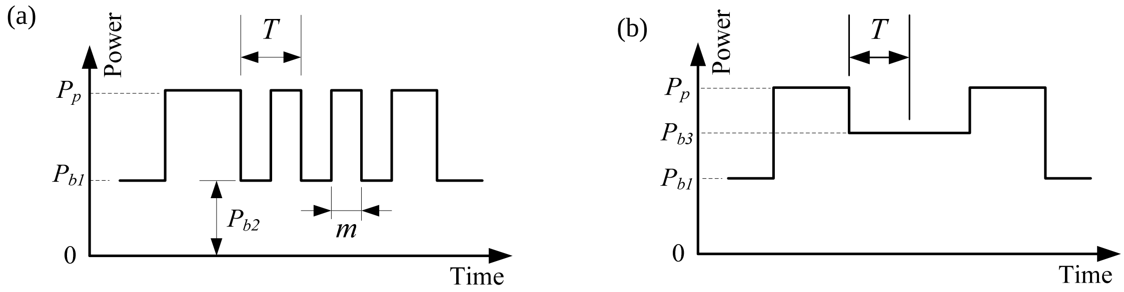


Fig. 2. Write strategy. (a) Multi-pulse type. (b) Castle type.

3. Experimental

A schematic cross-sectional view of an experimental disk is shown in Fig. 3. A phase-change material of Ge-Bi-Te system is utilized for the recording film in order to correspond to 16x-speed. The film thickness is 8nm. For obtaining a large cooling effect, Ag-alloy with high thermal conductivity is used for the reflective film. The phase-change layer is sandwiched between ZnS-SiO_2 films, and the thickness of the upper side ZnS-SiO_2 film was designed to be as thin as possible to enhance the thermal diffusion from the phase-change film to the reflective film.

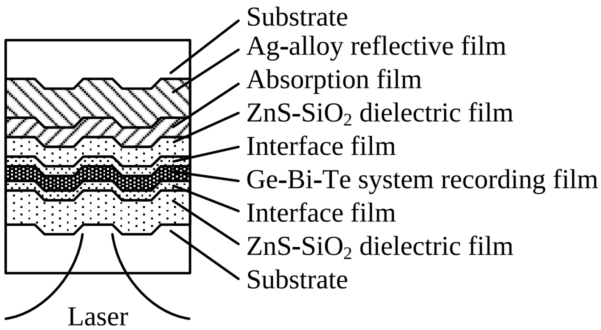


Fig. 3. Cross-sectional view of the experimental disk.

A dynamic disk tester (Shibasoku Co. Model LM330A) was employed for measurement of the recording characteristics of the experimental disks. Revolving speed of the disk is set in such a way that recording speed becomes 6x (24.6m/s), 8x (32.8m/s), 12x (49.2m/s) or 16x (65.6m/s). Playback speed was set to 2x (8.2m/s). In the tester, a write strategy shown in Fig. 2(b) was set for the disk evaluation. Edges of the pulses are adjusted to obtain the best jitter for each recording speed.

The disk evaluation was performed by the following procedures for each recording speed. Firstly, Carrier to Noise Ratio (CNR) of 3T marks was measured. Secondly, overwrite erasability of 11T marks on 3T marks was measured Then, the jitter values of random signal were measured. Here, we evaluated the jitters including the influences of cross talks and cross erases from the adjacent tracks.

4. Results and discussions

Shown in Fig. 4(a) are the experimental results of the relations between the peak power P_{p1} and CNR for three recording speeds. Figure 4(b) shows the experimental results of the dependence of the overwrite erasability on the bias power P_{b1}. For all the speeds, CNRs of more than 50dB and approximate 30dB of overwrite erasabilities are obtained. These values are equivalent to those of the conventional DVD-RAM disks.

Table 2 shows the obtained results of the jitters of the experimental disk at various recording speeds. Jitter values less than 9%, the criterion of DVD-RAM specifications version 2.0, are attained for every condition in both tracks (land and groove). These results indicate that this disk has sufficient recording performance in a wide range between 6x and 16x speed.

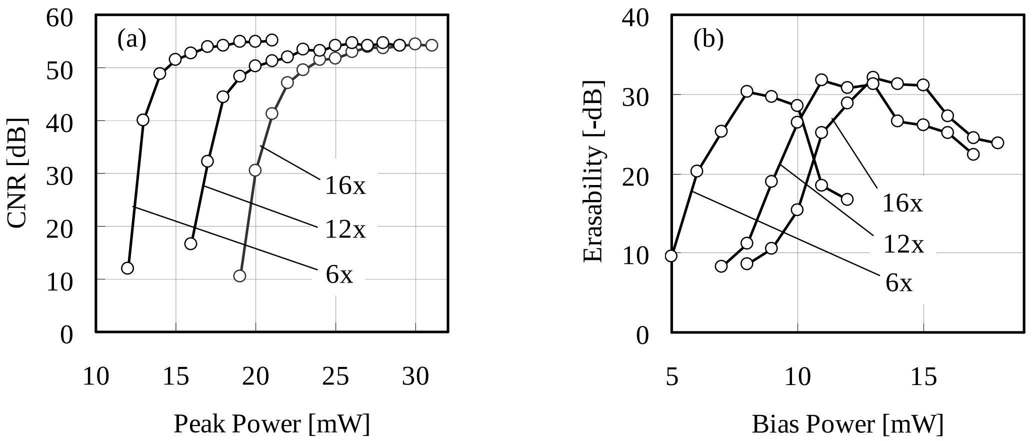


Fig. 4. Comparison of (a) CNR and (b) erasability among 6x, 12x and 16x recording speed.

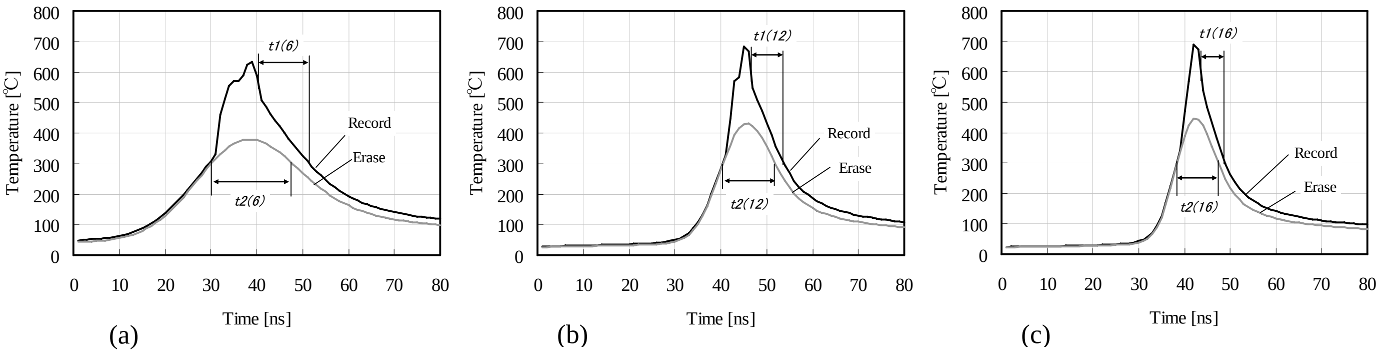
Table 2. Jitters of the experimental disk at various recording speeds

Recording speed (Disk revolving speed)		6x	8x	12x	16x
Jitter	Groove	7.7%	7.6%	7.9%	8.7%
	Land	7.5%	7.4%	7.6%	8.4%

Next, consider the implication of the wide tolerance of the linear velocity by calculating the heating-cooling process of the recording film during laser irradiations. Figures 5 show the simulation results of temperature profiles in the recording film of the 16x-speed DVD-RAM during recording and erasing processes. Figure 5(a), (b) and (c) corresponds to recording and erasing at 6x, 12x and 16x speed, respectively. “Record” means temperature profiles during irradiation of 3T recording pulse, and “Erase” means temperature profiles during irradiation of the bias power of DC mode.

Here, we define that the crystallization should proceed at temperatures between 570℃ (melting point T_m of the recording material) and 300℃ (critical point, T_x). Though the minimum temperature of crystallization of Ge-Bi-Te based film has not been determined clearly, yet, it is likely that crystallization may occur at somewhat lower temperature than that of the conventional Ge-Sb-Te based films. In the figures, t_1 is the time during which the recording film is kept between the T_m and T_x, and t_2 is the time during which the recording film is kept over T_x. Suffix numbers with brackets indicate recording speed.

In order to achieve recording (amorphizing) and erasing (crystallizing) using the same laser spot, the relation of $t_1 < t_2$ is satisfied for every condition. In addition, in order to utilize the disk at a certain recording speed ranging between X(max.) and Y(min.), one expects that the formula $t_{1(Y)} < t_{2(X)}$ has to be satisfied. That is, the crystallization time at the maximum speed X, $t_{2(X)}$, should be longer than the cooling time in the amorphization process at the minimum speed Y, $t_{1(Y)}$. As a range of recording speed becomes larger, the difference between $t_{1(Y)}$ and $t_{2(X)}$ becomes smaller. This is just the most important issue in the structure designing of the rewritable phase-change optical disks.



(a) (b) (c)

Fig. 5. Calculated temperature versus time of the recording film in DVD-RAM disk at (a) 6x, (b) 12x and (c) 16x speed.

As can be seen in the figures, from the calculations, the condition of $t_1 < t_2$ is kept for the every condition of 6x, 12x and 16x speed. For the relation between $t_{1(Y)}$ and $t_{2(X)}$, it is natural that $t_{1(6)} < t_{2(12)}$ and $t_{1(12)} < t_{2(16)}$ have been satisfied between 6x and 12x, and between 12x and 16x, respectively; however, $t_{1(6)} < t_{2(16)}$ has not been satisfied between 6x and 16x though we confirmed that the real experimental disk shows good performance in a range between 6x and 16x speed.

We think that the causes of the above disagreement exist in the somewhat rough premises of the simulation. One premise is the constant crystallization rate in the wide crystallization temperature zone, while the real crystallization rate will be larger at the higher temperature condition than at the lower temperature condition. Assuming the variation of the crystallization rate on the film temperature, it is possible that the erasing process at 16x speed proceed more swiftly by relatively shorter laser heating than at 6x speed. Because the temperature at erasing process is relatively higher in the 16x case than in the 6x case (Fig.5). Another premise is the constant thermal conductivity of the dielectric films, while the thermal conductivity of the dielectric films will be lower at the higher temperature condition than at the lower temperature condition. Supposing that thermal conductivity of the dielectric films decreases with increasing temperature, it is also supposed that the $t_{2(16)}$ should be practically longer than the present calculation result. Also in this case, it is noted that the temperature at erasing process is relatively higher in the 16x case than in the 6x case (Fig.5). At all events, ones find that it is just the point of the structure designing of 16x-speed DVD-RAM disk to cope with both crystallization at 16x speed and amorphization at 6x speed.

5. Summary

We have developed 16x-speed DVD-RAM disk. The first priority in the structure designing is consistently enabling crystallization at 6x speed and amorphization at 16x speed. For the target, we developled a new phase-change film of Ge-Bi-Te based alloy having a very large crystallization ability, and a rapid cooling layer stacking. The obtained disk has satisfied the DVD-RAM specification version 2.0 with sufficiently high recording performance over a wide range between 6x and 12x, and between 6x and 16x speed. The performance of the high speed DVD-RAM disk will be valuable to both audio-visual application and PC application.

References

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Biography

Kenji Narumi obtained a master degree in electrical engineering from Doshisha University, Japan, in 1993. In the same year, he joined Matsushita Electric Industrial Co., Ltd. He has been a member of a group for development of phase-change optical disks. From 2004 to 2006, he had led a project team of high-speed DVD-RAM media. His interests include measurement system and recording principle of phase-change optical disks.