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Invited Paper

Perspective and future of DVD-RAM

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ABSTRACT

This paper reports the perspective and future of DVD-RAM. The standardization of DVD-RAM and future technologies are described.

Keywords: DVD-RAM, Phase change media, Standardization, Land and Groove format

1. INTRODUCTION

To describe the perspective and future of DVD-RAM, firstly, the standardization of DVD-RAM is reported and secondly, the future technologies is reported.

2. INTERNATIONAL STANDARDIZATION

2.1 Standardization of DVD-RAM in 1999

DVD-RAM disk standard and case standard were proposed as DIS (Draft International Standard) with FTP (Fast Track Procedure) by Japan, and approved as an international
Standard (IS) through a post voting. After that, Annex L (Informative) was eliminated from ECMA standard of DVD-RAM. Then the organization SC23 heard an opinion of each country about a proposal of Annex L elimination, so that the elimination of Annex L was recognized. Based on this, the standardization document was sent ITTF(Information Technology Task Force) by SC23, and it was published as an international standard of ISO/IEC in May, 1999.
The number of international standard is as follows.
ISO/IEC 16824 Information technology - 120 mm DVD rewritable disk (DVD-RAM)
ISO/IEC 16825 Information technology - Case for 120 mm DVD-RAM disks

2.2 Specification and technology of next generation DVD-RAM

The physics specification of DVD-RAM ver.2.0 (4.7 GB / 4.7 GB / side), which is the next generation of DVD-RAM ver.1.0 (2.6 GB / 2.6 GB / side) was published in September, 1999. DVD-RAM ver.1.0, and ver.2.0 prescribe about a disk of 120 mm diameter, but 80 mm diameter disk will adopt the specification of physical format same as ver.2.0.
The specification which includes the specification ver.2.0 of 120 mm diameter and 80 mm diameter disk, is expected to be published in spring, 2000 as standard ver.2.1. The specification / technology outline is reported as follows based on DVD-RAM ver.2.0 specification published already.

(1)Basic specification of DVD-RAM ver.2.0
The most important characteristic of DVD-RAM ver.2.0 is to keep a downward compatibility. Even though recording bit length and track pitch were made narrow so that the recording capacity could increase with approximately 1.8 times from 2.6 GB per one side of ver.1.0 to 4.7 GB per one side, other physical specifications are not changed at all. Furthermore, a important characteristic is to make a data transfer-rate speed up to 22.16 Mbit / sec (Mbps), which is 2 times as fast as DVD-RAM ver.1. Main specifications of DVD-RAM ver.2.0, DVD-RAM ver.1.0 and DVD-ROM ver.1.0 are shown in table 2.2.1.

(2)Technology outline of DVD-RAM ver.2.0
In DVD-RAM ver.2.0, an interchangeability with DVD-ROM is attached importance like DVD-RAM ver.1.0
Thickness of disk substrate, laser wavelength, numerical aperture of object lens, are selected a value same as one of DVD-ROM. As for recording media a phase change media, which has the same read-out principle as DVD-ROM is adopted. Therefore, it is possible to read DVD-RAM by a head of DVD-ROM.

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In addition, modulation code and ECC (Error correction code) is adopted same system as DVD-ROM, so that the same signal processing circuit as DVD-ROM is utilized. Recording surface on a disk is divided into 35 zones with the shape such as a doughnut. ZCLV (Zoned Constant Linear Velocity) record system, which changes a rotation between zones and keeps it constant in each zone, is adopted in order to make a recording density and transfer-rate fixed from the inside to the outside of a disk. Here, sector number per a track at the most inner zone is 25.

As for recording format, Land and Groove format, which is able to be superior to cross-talk cancel same as ver.1.0 and make a track pitch narrow, is used. A overview of recording format is shown in figure 2.2.1 (a). Recording track consists of a spiral land and a groove. A land and a groove are connected with each other at one point in turn and the groove replaces automatically to the land (the reverse is also true), so that a single spiral track is formed. This track is wobbled with a single frequency and same phase.

Furthermore, a header part of each sector is arranged as a staggered shape at a boundary part between a groove track and a land track like ver.1.0, as shown in figure 2.2.1 (b). Identification information of each sector (ID, sector number) is formed in 4 folds (ID1, 2 show a sector number of a next land track and ID3, 4 show a sector number of current groove track) so as to decrease the possibility that an address information can't be detected by defects.

The address error rate is restrained even enough to be able to bear computer use by combination of this header construction with above mentioned wobbling of a track. Furthermore, in ver. 2.0, the following new functions are added to ver. 1.0.

(1)A flexible defect management method, to utilize the data volume effectively, was equipped with in Ver2.0, so that DVD-RAM can be applied for real-time AV recording.
(2) the adaptive recording control that recording pulse wave shape is changed according to recording pattern was adopted as shown in Fig.2.2.3. The control information for a adaptive recording control is pre-recorded as a table in a control information part on a disk. A drive system reads the table and uses it at recording, so that a most suitable recording is utilized.
(3)The same BCA as DVD-ROM is equipped with, and all disks are able to identify each other, so that data security is guarded perfectly in DVD-RAM.

As described above, in DVD-RAM ver.2.0, transfer rate of 22.16 Mbps, which is 2 times as fast as ver.1.0 are realized. It is expected that application for DVD-RAM spreads by a higher transfer-rate. For example, when recording a picture of MPEG2, many channel of normal TV quality is able to record simultaneously, and record the most high quality picture of MPEG2 needed transfer-rate of 15 Mbps. About the details of specification of DVD-RAM ver.2.0, refer to DVD forum publication.

3. FUTURE TECHNOLOGY

3.1 Introduction

2.6 GB per one side of DVD-RAM really went to a market last year, and a technology announcement for DVD-RAM of 4.7 GB per one side and DVD-R/W was done as the next product. Furthermore, the technology development that realize a phase change disk of larger capacity is proceeded. So, a trend of a future technology of phase change optical disk was investigated. A high density read/write technology is described in 3.2, media technology is done in 3.3, and other technical is mentioned in 3.4.

3.2 High density read/write technology

In DVD-RAM, a road map to achieve a recording capacity 15 GB / one side as a next generation is announced clearly as shown in Fig.3.2.1, but possibility of the more large capacity is examined because the capacity of more than 20 GB is required in order to record a signal of HD broadcast (HDTV) (TS stream of MPEG2) for more than 2 hours.

As for blue violet semiconductor laser, which is a key component for higher density, a laser of low output power of GaN which is available for a read-only type optical disk went on a market in October, 1999.
The rated output power is 5mW, and maximum power is 10mW. The life time is 10000 hours at room temperature, and 1000 hours at 50 ℃. Other 4 companies reported continuous emission of GaN blue violet laser at room temperature. On the

other hand, a high power laser of the order of 30 m W is needed for recording, but the emission for 400-500 hours with light output 30mW at 60 ℃ has been already reported [1]·and the continuous emission with 30 mW at room temperature is reported by some organizations. [2]· The development of high output power laser of blue violet GaN is accelerated.

However, reports about read/write technology using GaN laser are still limited [3),4),5),6)] because it is difficult to get a high output power laser of blue violet GaN. Many reports is related to read only optical disk system. As for a rewritable optical disk system, there are very many reports using Kr ion gas laser instead of blue violet semiconductor laser at present. However, it is thought that reports using a blue violet GaN laser increase.

As for cutting technology of master disk, which is fundamental for higher density, there were two remarkable reports. [7)]
(1)The technology of Deep-UV cutting using
266nm solid laser has been already reported. In addition, record wave shape is controlled and jitter value is improved. Kr ion laser is used for read-out evaluation, and factors of jitter ingredient is analyzed. This technology needs a special developing process for chemically amplified resist. (2)Near field technology, which uses SIL(NA=1.4), was combined with blue ion gas laser and applied for cutting machine. The method that uses piezo device or air suspension in order to control a narrow gap between SIL and surface on disk is proposed.[8]· This technology doesn't need a special process such as a mastering using 266nm laser. So, a current developing process is continued to use even at next generation.

As for increasing a capacity and transfer-rate for the next generation of DVD, there are two flows. One is to attach importance to interchangeability with current DVD, the other is to make NA higher than current optics combined with thin cover layer. The former technology is based on shortening laser wavelength and so on, can reach a capacity of the order of 15 GB. The latter technology doesn't succeed in a current read-out principle that a substrate doubles with a cover layer and separates each other. The aberration caused by high NA is eliminated because light goes through thin cover layer. This technology demonstrated a experimental result of 8 GB using red laser and possibility of 22 GB using blue violet laser.

These are described in detail as follows.
When reaching the capacity of 15 GB combining same substrate and NA as DVD with blue laser, all kinds of margin get narrow. The many means are proposed to solve this problem.[9.,10.,11.,12.] There are cross-talk chancellor for track offset reduction and tilt compensation technology. Four axis lens actuator that has tilt compensation and mechanism for tilt compensation that mirror changes in two axis are proposed.[13]·

As for a system using a high NA lens and thin cover layer, a joint research is announced as HD picture recorder system of next generation.[3.,5.,6.] Element technologies have already reported, but an announcement compromised these as a concept of recorder has never been. A recording layer is formed on substrate of 1.1 mm thickness, and the cover layer of 0.1 mm is formed on it by spin overcoat and laminate sheet, so that the disk is formed. Thickness allowance of a cover layer is ± less than 3 micron meter. New ECC which reinforces error correction ability against a dust, a fingerprint, and wound because the cover layer is thin is proposed. Modified (1,7) modulation code to improve DC suppression capability is adopted. As for track format, land and groove construction wobbled is adopted same as DVD-RAM and zone CAV to shorten access
time is adopted. The format efficiency becomes 79 % between 75 % of DVD-RAM and 84 % of DVD-ROM. The experiment result that uses red laser demonstrated capacity of 9.2 GB, data transfer rate of 33 Mbps were provided, and real-time recording of compressed HD picture. If blue violet laser is used for this system, large capacity of 22 GB is expected.

As another approach for higher density of phase change medium, a experimental result of multi-level recording is reported.[4]· By using four level, it is mentioned that CNR reached more than 50dB. Furthermore, as means of other promising approach, there was a great progress in super solution technique. The organic dye which can be made by spattering has a reversible characteristic of transmission and high sensitivity at blue wavelength is provided. The read-out principle are known RAD (Rear-aperture detection) types in magneto-optical disk. The effect of super resolution is proven since this method can read out a signal of 0.2 μ m mark from RW phase change media recorded crescent marks with variable length to 0.15 μ m. It is demonstrated that this method can reach approximately two times as large capacity as RW disk.[5]·

3.3 Media technology

(1) medium construction

To record HD picture, not only large capacity but high data transfer-rate are required. Therefore, the media with construction suitable to high speed recording has been developed. The medium construction that Si layer was added to GeSbTe recording layer, its recording layer was put with SiC layers is developed in order to establish heat balance of horizontal and vertical directions and make crystallization velocity fast, so that transfer rate improved to 36 Mbps.[16.] Double layer per one side disk added Al layer to this construction is developed, so that capacity of online access increases to 16.8 GB and data transfer rate becomes 27 Mbps.[15.] Problems of double layer per one side such as leak to signal from embossed header of under layer and deference of recording power between double layers are pointed out.[17.]

Furthermore, in the case of recording method combining high NA and the thin cover layer with blue laser, it is investigated to improve media construction for high date transfer rate, too.
Using SiN instead of SiC raises up crystallization velocity and obtains data transfer rate of 35 Mbps. Jitter of 8 % is provided under the condition of capacity of 22 GB.[17]

(2) recording materials
As for recording materials, GeSbTe have been mainly examined to satisfy the demand of higher data transfer rate and many cycle times such as DVD-RAM. However it has been reported recently that even AgInSbTe are possible.[18.] It is assumed that transfer rate becomes fast when mark becomes small by small recording spot depended on difference of erase process in the case of AgInSbTe. It is assumed that a combination of 685nm and NA0.6 makes transfer-rate of more than 41Mbps possible and combination of 400nm and NA0.85 makes transfer-rate of 50 Mbps possible. It is hoped to investigate more in detail from point-view of selecting material.

To eliminate initialization of DVD-RAM, new construction that Sb_2Te_3 was added to recording layer makes crystallization easy at lower temperature and crystallization velocity fast is reported.[19.]

3.4 Simulation of phase change mechanism

There are many reports about simulation related to read/write mechanism of phase change media.[20.21.22.] One uses a molecule orbitacle model and tries to explain a transition between crystallization and amorphous of phase change media.[20.] It is possible to succeed in macro model mentioned next.

The through simulation from recording process to reading process using the macro model has been already reported. This simulation is applied for 4.7GB DVD-RAM. It is proven by comparing a experimental data with a simulation result that an adaptive control method that is introduced for interchangeability is effective.[21.]

3.5 other technology

As for near field recording, it is remarkable report that a smaller aperture than wavelength was arranged in an surface of semiconductor laser and marks are directly recorded on a phase change media of GeSbTe without an optics.[23.] The aperture is 250nmnm , CNR is obtained 45dB under the condition of line and space of 150 nm, and track pitch of 500nm, recording rate becomes 24 Mbps. It is hoped to make more speed up when narrowing the aperture.

As for super resolution technology, super-RENS has a big progress. Reflection construction is adopted, and SNR can be improved largely using AgOx as
materials.[24.] Furthermore, novel super resolution technology that use the beat effect in a spacial frequency with a grating is proposed.

3.6 Summary of future technology

(1) The recording method combining high NA and thin cover has realized higher transfer-rate and larger capacity.
Furthermore, transfer-rate of 35 Mbps is necessary for HD picture but this rate has been limited to 18 Mbps. However, combination of blue violet laser and improvement of media construction rises up transfer rate to 35 Mbps.
(2) The output power of 5mW of blue violet GaN laser has gone on market. As for the high output power laser of 30mW, continuous emission at room temperature for 400-500 hours was reported. The blue violet GaN laser has progressed greatly toward practical use.

(3)There are a proposal of VSAL(very small aperture laser) technology and demonstration of possibility of higher density using this device, report about CNR improvement in super-RENS by reflection construction and so on. The possibility to further high density recording progresses.

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Table 2.2.1 Main specifications of DVD-RAM

Items	DVD-RAM ver. 2.0	DVD-RAM ver. 1.0	DVD-ROM ver. 1.0
Capacity	4.7 GB/side	2.6 GB/side	4.7 GB/side
Transfer-rate	22.16 Mbps	11.08 Mbps	11.08 Mbps
Diameter	120 mm	120 mm	120 mm
Thickness substrate	0.6 mm× 2	0.6 mm× 2	0.6 mm× 2
Recording method	Phase change	Phase change	Embossed pits
Wavelength	650 nm	650 nm	650 nm
NA	0.6	0.6	0.6
Bit length	0.28 μm	0.42 μm	0.267 μm
Track pitch	0.615 μm	0.74 μm	0.74 μm
Track format	Wobbled L&G	Wobbled L&G	Pits line
Physical address	Embossed pits	Embossed pit	Embossed pits
Modulation code	RLL(2, 10)8-16	RLL(2, 10)8-16	RLL(2, 10)8-16
Sector size	2048 B	2048 B	2048 B
ECC	RS Product code	RS product code	RS product code
Block of ECC	16 sector	16 sector	16 sector
Recording(zone)	ZCLV (35 zones)	ZCLV (24 zones)	CLV
Defect management	resent	present	none

DVD-RAM Disc Outline

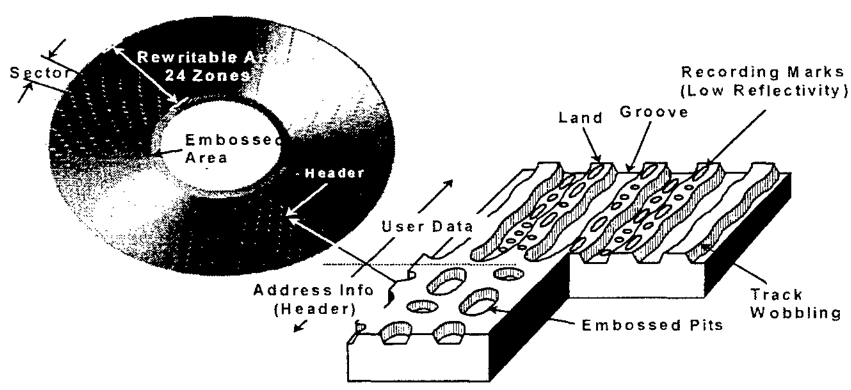


Figure 2.2.1 (a) Outline of DVD RAM format

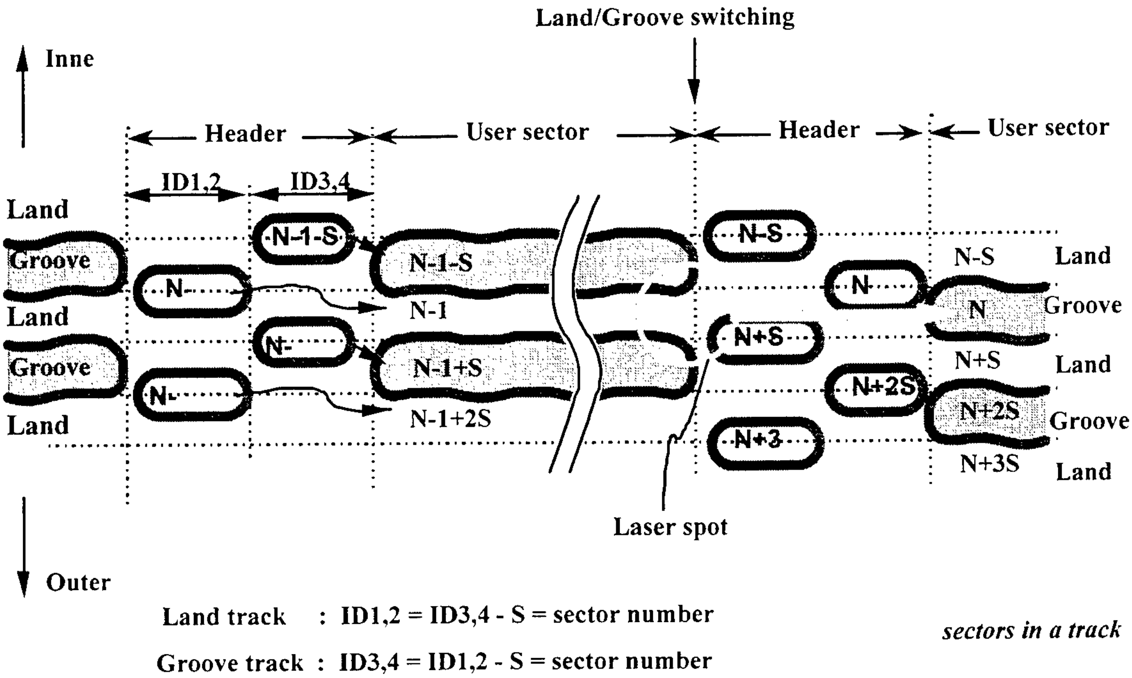
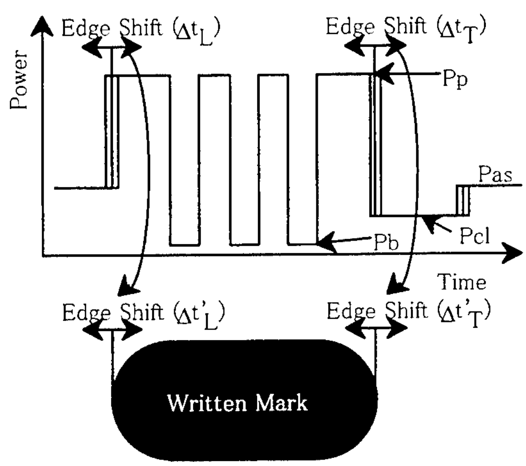


Figure 2.2.1(b) Outline of track format of DVD-RAM



(a)

Δt_L (nsec)	Mark length (nT)			
Space (aT)	3T	4T	5T	6T−
3T	3	1	0	-1
4T	3	1	0	-1
5T	4	2	1	0
6T−	4	2	1	0

Δt_T (nsec)	Mark length (nT)			
Space (bT)	3T	4T	5T	6T−
3T	−4	−3	−2	0
4T	-3	-3	-1	1
5T	-4	-4	-2	0
6T−	-4	-4	-2	0

(b)

Fig.2.2.3 Adaptive Write Compensation (a) Write waveform (b) Write table

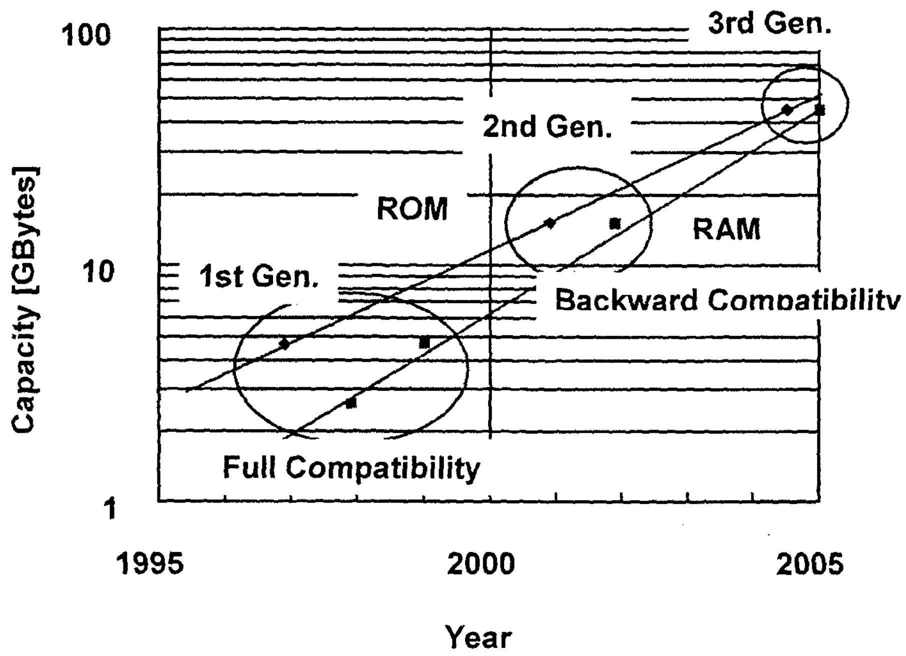


Fig.3.2.1 Road map of DVD