Archiving Solution with Optical Disc

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Abstract

Ever since the dawn of human being, variety of media such as stone, parchment, bamboo, woods, paper, magneto, optical and electric has been used for recording information. Among those, the optical discs initially started from audio CD in early 1980s, has 12 cm diameter, still playing prominent roles for long term with its stable format, despite the continued evolution of electronic products. The recordable optical discs has also been used for data storage and data distribution for more than 20 years showing its continued strong demand over 10 billion discs every year. Its applications are broadly ranged such as audio, video, PC and digital information.

Though optical discs have less capacity and slower transfer rate than hard disk drives and magnetic tape, they have great deal of potential for application of long term archiving.

This report discusses the use of optical discs as archiving media and trends in its standardization towards it. As an example, this paper also examines the recovery of discs damaged by the Great East Japan Earthquake.

1. Introduction

Throughout the history of human being, recorded information has contributed to the prosperity of cultures. While the medium of recording has evolved over the millennia, from stone, wood, and clay to bamboo panels, papyrus and paper, and, more recently, to magnetic and optical media, the need for a method of archiving of information has been a perennial one, as each generation seek is a means of passing on its history and knowledge to posterity. Today, with the explosive increase in the sheer volume of information, as well as potential threats to data integrity such as environmental problems, cyber terrorism and natural disasters, the need for a versatile and reliable long-term archiving solution is greater than ever. It has been more than three decades since CD(Compact Disc), was first introduced and more than two decades since the first CD-R(Compact Disc Recordable) was introduced. Despite the rapid and continuous evolution of electronic products over this period, such internationally standardized optical disc formats remain as consistent and reliable for long term unlike others. With worldwide demand of over 10 billion, CD/DVD/Blu-ray optical discs are now used for data storage and distribution in many applications such as audio, video, images and PC data. The total number of record/playback drives has exceeded 4 billion units, and Blu-ray drives, which are expected to sell in large numbers, are also capable of playing CD and DVDs. And ROM disc contains music and movies sold in the past, which accumulative numbers are huge, continues to be existed in the filed. Thus CD sized optical disc including rewritable and write once, ROM, are formats securing playback for long term, if those are internationally standardized, and expected to be around far into the future.

Taking above mentioned into consideration, the following factors to be consider as necessary for digital data archiving.

1) Adopting physical formats which are set as international standard, avoiding some preliminary formats set by individual manufacturer.
2) Records data based on logical formats set by international standard.
3) Operate based on international standards.

The optical disc has less capacity and slower transfer rate than hard disk drives and magnetic tape, but it is much more suitable for long-term archiving. The HDD is suitable for handling data with high access frequency, while the optical disc is suitable for long-term archiving of fixed data that does not need frequent access. Using the optimal storage medium according to the data access frequency makes it possible to build a system capable of archiving data securely.

In the rest of this paper, the authors will discuss the use of the optical disc as an archiving medium for distributed or offline storage, together with trends in its standardization. As an example, we will also examine actual cases of the recovery of discs damaged in the Great East Japan Earthquake.

2. Long-term archiving of information

The lifecycle of large-volume document (book) based information can start when it is digitized into electronic data, which is more flexible and easier to work with than paper information. Fig.1 shows the diagram of the information lifecycle.

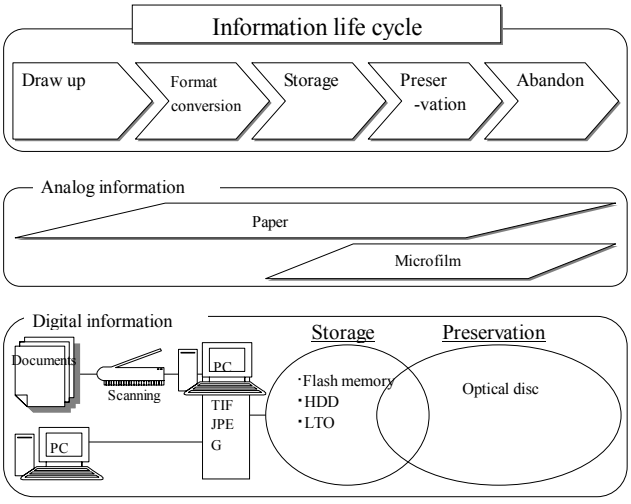


Fig.1 Lifecycle of information

The digital data obtained by data conversion is then transferred to an HDD for editing and processing. However, considering the increase in the volume of data and the service life of HDDs, data that is not frequently accessed and that requires long-term archiving should be stored on optical discs for the following reasons:

Optical discs can be read out without contact so there is virtually no degradation itself. Optical discs do not need a power supply or special environment for storage. As the disc format has been already been around for a long time, storage is possible with minimum labor and management. ISO lifetime expectancy testing estimates that the lifespan of an optical disc can be as long as over 30 years if proper media and recorder are selected.

Naturally, the optical disc has some disadvantages, such as small capacity and slower data access rate. This makes it necessary to select the optimum medium according to the data access frequency (the stage in the lifecycle).

3. Long-term archiving on optical disc

(1) Mechanism of recording and error production

Fig.2 shows a simplified diagram of the optical disc recording/playback mechanism. The laser beam is irradiated on an optical disc to form the signal recording area called "pits" as shown in Fig.3. A laser chip is used so non-contact recording/playing of data is possible. Specifically, this system forms small pits with variable lengths on the disc substrate using the heat of the laser beam, and reproduces data based on the combination of pits with variable lengths. Thus, a read error is generated when the length and position of formed pits are deviated. The optical disc system is equipped with a powerful error correction system which corrects signal read error against fingerprints and dust. However, when foreign residue exceeds a certain level, errors can no longer be corrected and the data become irreproducible. With BD-R discs, which have a very high recording density, the signal can be as short as 0.149 μm, so extremely sophisticated control is required. Cause of error is from 2 factors. One is from pits mark. The other is from defect. And defect makes error level deteriorated by corrosion. The mechanism of error production can be seen in Fig. 3 which shows the gradual expansion and disappearance of pits formed in recording, and in Fig. 4, which shows the extension of corrosion around a defect (dust, grease, etc.) that functions as the core. Based on this knowledge, the degree of degradation can be identified correctly by using the error values specified in JIS Z6017 archive migration standard.

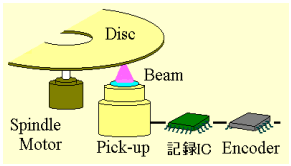
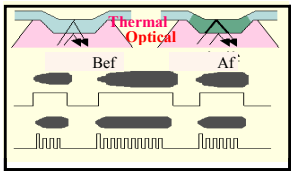


Figure 2 : Mechanism of Recording



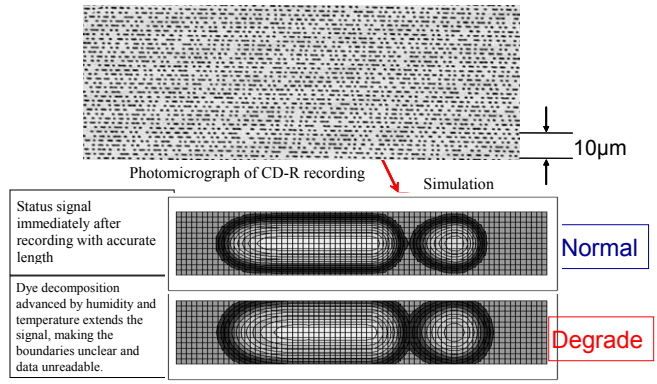


Figure 3 : Pit formation and error

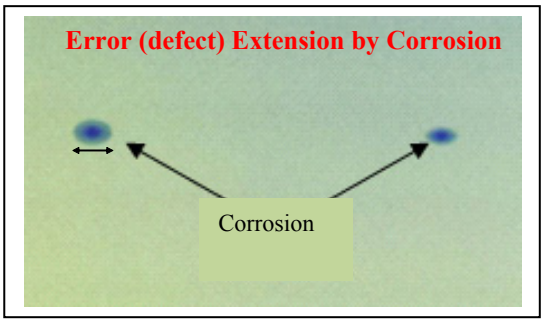


Figure 4 : Error extension by corrosion

(2)Standards related to long-term archiving on optical discs

In long-term archiving of digital data, it is important that the margin of error before the data becomes irreproducible is as large as possible. In other words, it is important to reduce the initial error value to as low a value as possible and to use a disc designed for long-term archiving. The main Japanese and international standards include the following (Table 1).

1) Standards for migration: JIS Z6017, ISO/IEC 29121

2) Standards for test of estimating lifetime expectancy ISO/IEC 10995, ISO 18927, ISO/IEC 16963

Similar standards are also being elaborated for BD and are expected to be announced in the near future. [1][2]

Table 1 : Standards related to optical disc archiving

		Format standard	Life test standard	Operation standard
CD	ISO	ISO/IEC 10149	ISO/IEC 18927 ISO/IEC 16963	—
	JIS	JIS X6281	—	JIS Z6017
DVD	ISO	ISO/IEC 16448	ISO/IEC 10995 ISO/IEC 16963	ISO/IEC 29121
	JIS	JIS X6241	—	JIS Z6017
BD	ISO JIS	Being standardized by industry organization		

(3) Initial characteristics of DVD media

There are many different kinds of DVDs from numerous numbers of suppliers, and their recording quality can vary widely.

This is one of the reasons why many have questioned the suitability of optical discs for long-term data preservation. Fig. 5 shows the recording characteristics, represented by the PI error values, of DVDs of various makes as a reference for selection of the most suitable optical disc for archiving.

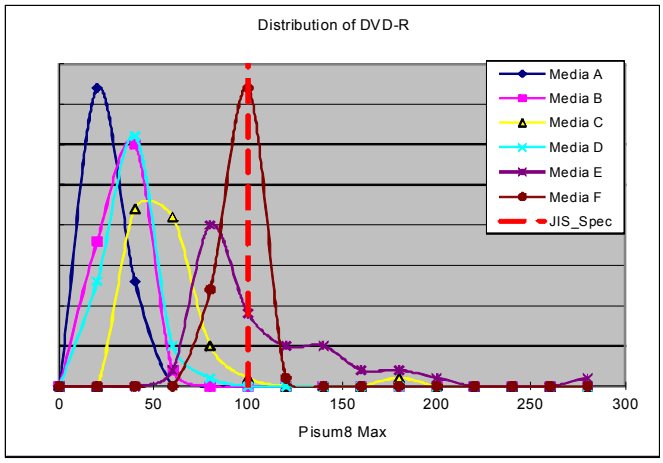
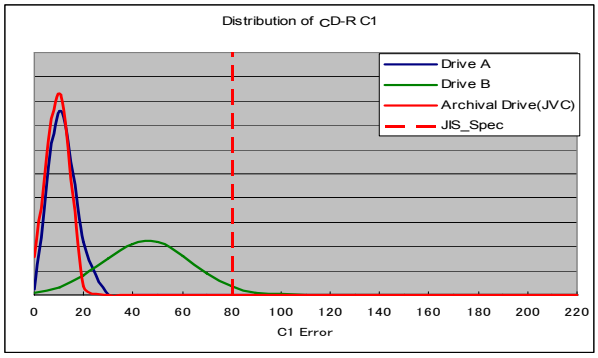


Figure 5 : DVD-R error distribution by suppliers

In this test, the authors measured the PI error values of each make of DVD disc (N = 50) and plotted the error value distribution of each disc type, assuming that the maximum PI error value of each disc type is the representative value of that disc type. However, it should be remembered that this defines the initial errors for an archiving application presupposing operations compliant with JIS Z6017, and that it does not mean a level at which data reproduction is impossible. Considering the existence of such variance even in initial values, the necessity of selecting the optimum DVD type is made clear by this graph.

(4) Initial characteristics of DVD recorders

There are also many different kinds of optical disc recorder from variety of suppliers, but no study has been made presupposing operations compliant with ISO/IEC29121. Fig. 6 shows the recording characteristics of DVD drives of various makers by assuming that the PI errors are the representative values of each drive.



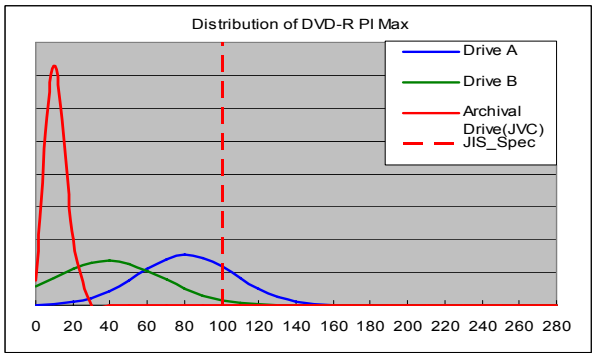


Figure 6 : Distributions by CD-R/DVD-R drives

In this test, the authors recorded data on JVC archive-grade CD-R/DVD-R media using different drives, assuming that the maximum CI/PI error value of each drive as the representative value of that drive. The authors measured N = 10 to 30 units per drive model and plotted the distribution of maximum errors for each drive model. Considering the existence of such variance even in initial values, this graph makes very clear the importance of selecting the optimum drive.

(5) Reliability of optical discs

The reliability of optical discs can vary widely from one brand to the next, providing another reason to question the preservation quality of the optical disc. Fig. 7 shows the storage environment characteristics of CDs from various makers, based on the number of C1 errors measured.

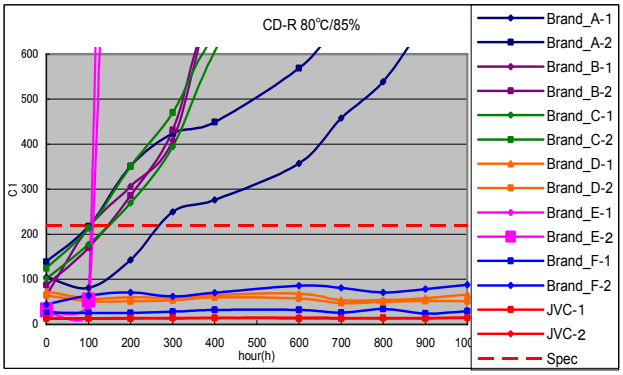


Figure 7 : CD-R reliability at 80°C, 85%

Fig. 7 shows that some discs present noticeable increase in C1 errors as a result of storage in the 80°C, 85% environment. This fact indicates the necessity of selecting an optimum disc compliant to the lifetime expectansy test standards (ISO/IEC 10995, ISO/IEC 16963).

(6) Secure long-term archiving

To use optical discs for secure archiving (long-term storage), it is required to;

1) perform operations compliant standards such as JIS Z6017, ISO/IEC29121;
2) use disc that passes the lifetime expectancy test set by such international standards as ISO/IEC 10995;
3) use dedicated archival recorder (drive) and dedicated optical disc (Fig. 8).

Operating and managing the system in compliance with standards such as ISO and JIS and selecting the optimum optical disc and recorder drive enables secure long-term storage of digital data.

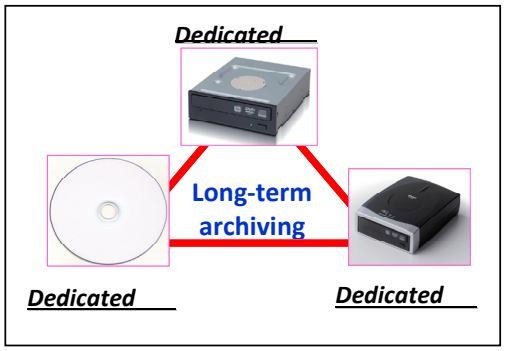


Figure 8 : Ideal optical recording system

In summary, secure long-term archiving can be assured by achieving recording characteristics with a low error value based on a combination of drive and disc with low individual variances as shown in Fig. 8 and managing the medium as required using a dedicated tester.

Victor Advanced Media Co., Ltd follows this practice by offering this tri-fecta.

(7) Actual achievement of optical disc storage

Optical discs are much less sensitive to temperature and humidity than microfilm and magnetic tape, making them easier and cheaper to store and preserve. They can be stored in a normal office environment and still attain the required lifespan. Although this presupposes a properly managed production process with reliable quality management, the extended lifespan can be largely attributed to the minimal degradation of recorded signal quality resulting from temperature and humidity.

Fig. 9 shows the error value of a CD-R recorded 20 years ago. The disc has been stored in a normal office environment, but no significant change in the error value can be observed.

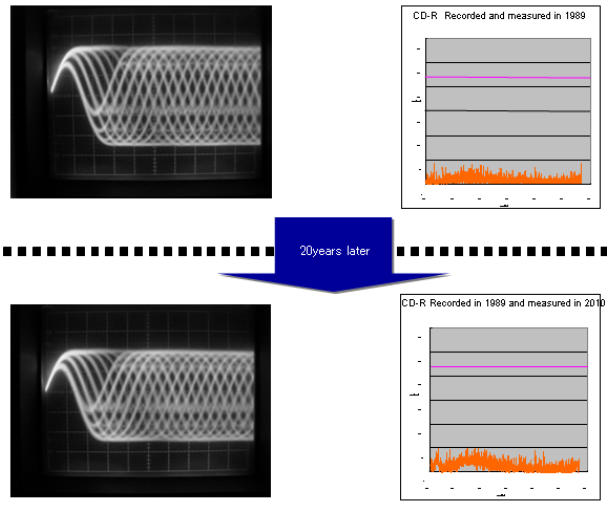


Figure 9 : Error value measurement of a CD-R stored for 20 years in general office environment.(on a shelf not exposed to direct sunlight)

4. Actual cases of recovery of recorded media damaged in the Great East Japan Earthquake

Fig. 10 shows an optical disc soiled by the massive *tsunami* generated by the Great East Japan Earthquake on March 11, 2011.

Figure 10 : Optical disc soiled with seawater and mud.

In spite of serious soiling by saltwater and mud, recovery of the optical disc was relatively easy. This is because the optical disc has a very simple physical structure and is designed to tolerate some degree of soiling by fingerprints, dust and scratches. This is particularly applicable to the DVD medium, in which the recording medium is sandwiched between two 0.6 mm plastic plates. The disc shown in this figure has a hard coating so the damage to the disc substrate due to mud, salt, etc., was minimized.

A leaflet entitled "How to Handle Optical Discs Soiled by Seawater or Mud" published by the Japan Recording Media Industries Association on its Japanese website is summarized below.[3]

(1)Rinse dirt away with fresh water such as tap water. If the stain cannot be completely removed, use a dedicated optical disc cleaning kit. Do not use an ordinary detergent because it may affect the optical disc surface.

(2)When dirt has been removed completely from the disc, wipe any moisture away. The use of a dedicated optical disc cleaning cloth is recommended. Wipe with a light force in the radial direction (linearly from the center of disc to the outer periphery).

(3)After wiping moisture away, dry the disc. To avoid disc warping during drying, stand the disc up and protect it from direct sunlight. It is recommended to put the optical disc in the case so that the recording surface faces the front, half-open the case, stand it up and leave it for at least 24 hours as indicated.

(4) After drying, it is recommended to copy the data on the disc to a new optical disc.

As indicated above, it is highly likely that it will be possible to read an optical disc without using a special tool or technique even in the event of a serious disaster. In other words, optical discs are highly suitable as an archiving solution for preservation of critical data (minimum amount of data required in emergency).

Like the optical disc, magnetic tape is also regarded as an effective means of offline storage.

Fig. 11 shows photos of a magnetic tape (VHS-F) soiled by the tsunami generated by the Great East Japan Earthquake on March 11, 2011.

Figure 11 : Magnetic tape soiled with seawater and mud

Mud has penetrated the cassette shell. This tape was recovered by;

(1) Removing mud from outside and inside the cassette with a brush;
(2) Repeated cleaning of the magnetic tape by hand;
(3) Replacement of required parts;
(4) Function check, and migration to another medium.

Figure 12 : Cleaning of magnetic tape

As shown above, recovery of magnetic tape is also possible. However, the process is considerably more difficult and labor-intensive than with the optical disc. Recovery of data from an HDD, typically seen as a primary storage medium, requires advanced specialized techniques. Therefore, the superiority of optical discs is obvious even in the event of emergency.

5. Conclusion

The lifespan of an optical disc can be extended for 30 years or more by reducing the initial recording errors and selecting the optimum medium for long-term archiving. As the optical disc is also advantageous with respect to data loss, environmental load, total cost and security, it will continue to be regarded as a medium highly suitable for archiving.

In closing, the authors would like to express their gratitude to Taiyo Yuden Co., Ltd. for their cooperation in the provision of data used in this report.[5]

References

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[2] Committee of Japan Image and Information Management Association, "Standard of Guide Book 2008", Japan Image and Information Management Association, Tokyo, 2008, p.1.

[3] Japan Recording Media Industries Association, "*KAISUI YA DORO WO KABUTTA HIKARI DISUKU NO TORIATSUKAI HOHO* (Handling Method of Optical Discs Soiled by Seawater or Mud)", 2011 http://www.jria.org/personal/pdf/info20110704.pdf

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Author Biography

Masaru Hanayama has a Master in physics from Tokyo University of Science(1982). Since then he has worked in Victor Company of Japan, Limited. His works has been focusing on development of magnetic tapes and optical discs.