

# **Long life and Recyclable disc for archival data storage**

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**Panasonic**

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## 1 Introduction

Long media life and reliability of stored data are the most important factors for archival data storage. Total amount of Storage data will increase significantly and reach up to several tens of zettabytes by 2020. To protect data loss and reduce maintenance cost, it is required for storage media to have higher reliability and longer media life from the market. In optical storage, write and read operation can be performed by non-contact focused light. This characteristic can provide a better solution for data storage. In addition, recyclability is a key concern since huge amount of storage media will be reversed by erase request from the customers. This document reports the reliability of Panasonic 300GB Archival Disc under actual operational conditions, estimation of the media life and recycling approach.

## 2 Structure of 300GB disc

Figure 1 shows the structure of 300GB AD (Archival Disc). 300GB AD disc is a double sided disc composed of two 0.5mm plastic substrates with triple recording layers. Data-capacity of each side is 150GB and total capacity of the AD disc adds up to 300GB. AD disc has 3 recording layers formed on a plastic substrate and there is a cover layer on top of recording layers (Table 1). In addition, space layers are inserted to separate each recording layer. Each recording layer consists of an oxide recording material film which is sandwiched by dielectric oxide material films so they are all oxide materials. Since thickness of each recording layers is less than sub-micrometers, disc is composed mostly by plastic which also allows easy material recycling.

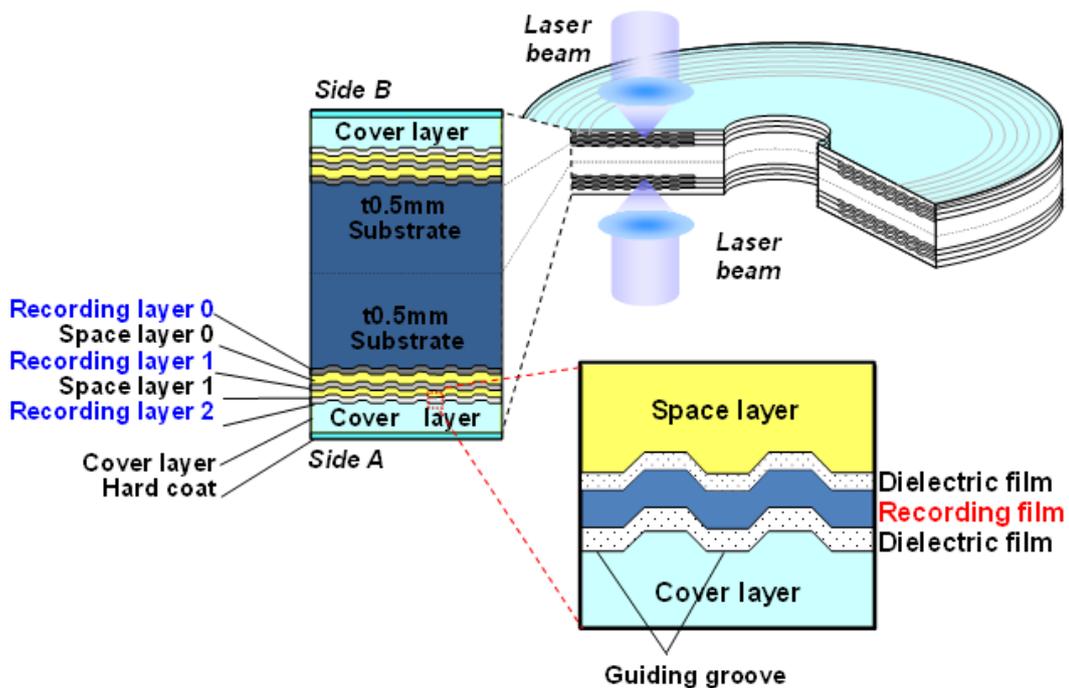


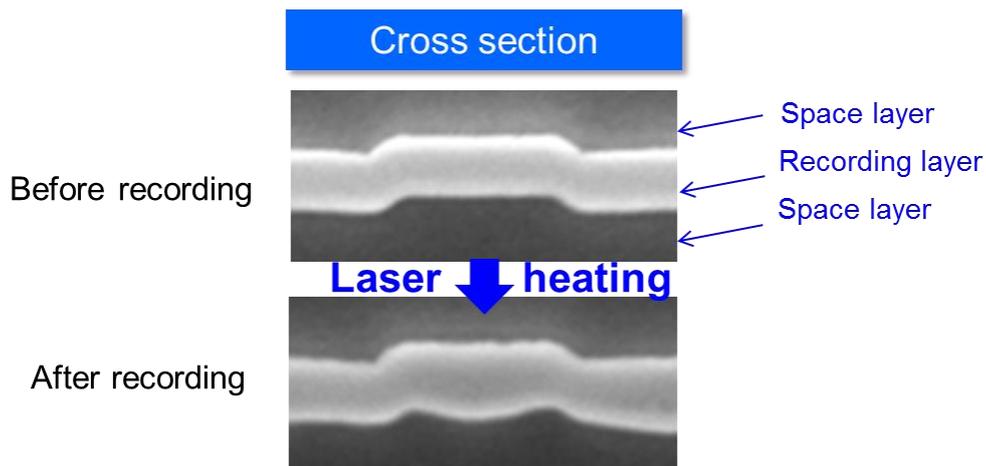
Figure 1. 300GB disc structure

Components	Materials	Comment
Cover Layer	Acrylic resin	Same as conventional optical disc material
Hard Coat	Acrylic resin	Same as conventional optical disc material
Space Layer	Acrylic resin	Same as conventional optical disc material
Substrate	Polycarbonate plastic	Same as conventional optical disc material
Dielectric film	Oxide	Does not include rare metal or noble metal
Recording film	Oxide	Does not include rare metal or noble metal

**Table 1.** The constitutive material of 300GB disc

As for the oxide recording material, its recording mechanism is deformation of film stack. Since recording marks are formed by change of physical shape, the recorded data is considered to be very stable. Figure 2 is cross sectional views of recording layer. Upper picture is before recording and lower picture is after recording. You can see the deformation of recording film stack.

Other advantage of this 300GB AD is that all recording layer films consist of oxides materials. In Figure 3, you can confirm that Panasonic's 300GB AD is transparent. Since it does not include light reflective metal film, there is no concern about metal erosion. It is durable against environmental change such as temperature and humidity while, for example, DVD-R discs which have dye-recording film and metal reflective film tend to deteriorate in the high temperature, humidity or sun-light exposure environment. Thanks to both features, storage reliability is improved and the 300GB disc has become more suitable for long-term archival media.



**Figure 2** Cross sectional views of recording layer stack



Figure 3 300GB Disc (recording layer is highly transparent)

### 3 Media life

#### 3.1 Media life test method

It is considered that the degradation of optical disc in its life time occurs by the change in the characteristics of functional thin films (such as recording film or reflective film which mainly composes the recording layer) which are caused by chemical reactions such as diffusion of water. When the degradation cause follows the reaction speed theory, we can treat the relationship between the given stress and reaction speed as Arrhenius model or Eyring model. Thus, the life time can be estimated by the acceleration test with the stress of temperature or/and humidity. The test method is specified in ISO/IEC FCD 16963.

\*) Eyring model: "Paul A. Tobias and David C. Trindade: Applied Reliability (3<sup>rd</sup> Edition) 2011, p273-278.

#### 3.2 Archival life time estimation result of the disc

We have conducted acceleration test to estimate the expected life time of Panasonic's 300GB discs by Arrhenius method. As a result, our 300GB discs are considered to have at least more than 40 years of lifetime at a temperature of 40 °C and humidity of 80% as shown in Figure 4. The estimation time in Figure 4 is calculated based on the experimental results at 90 °C / humidity of 80% and the acceleration parameter by the Arrhenius model. Bit error rate in Figure 4 is the worst ECC block in all data area of the disc.

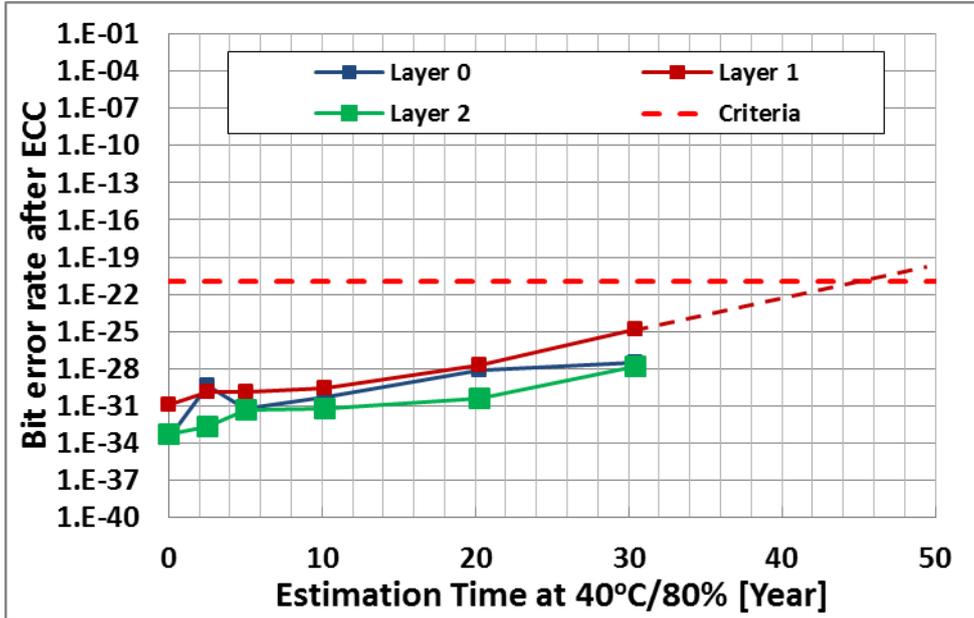
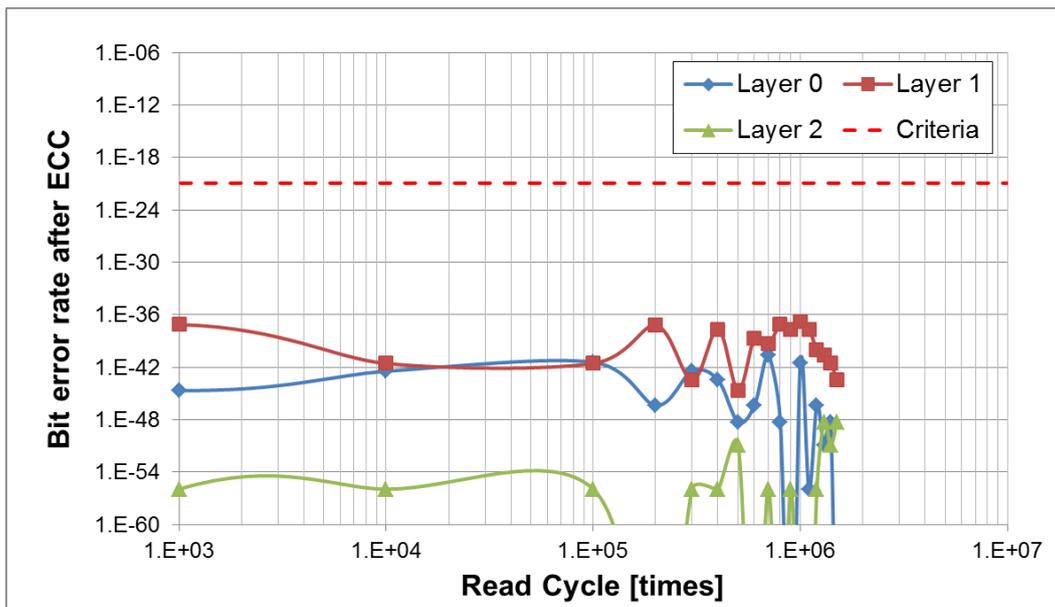


Figure 4 Media life test result

### 3.3 Read stability

In the AD specification, read stability of more than 1 million times is required and Panasonic’s disc sufficiently complies the specification. Figure 5 shows the results on read stability test. There is no degradation on error rate even after 2 million times reading on layer 0 and at lowest read speed (4X) that are worst condition for read stability.



**Figure 5** Read stability test result

### 3.4 Additional reliability test result

ISO Eyring test is a good method for estimating media life but other duration modes should be tested to guarantee the media reliability in future. Panasonic's 300GB disc is tested on many items that are specified by the feedback from market failure in the history of the optical disc business. The 300GB disc can write and read without uncorrectable error after the following test (Table 2).

**Table 2.** Additional reliability test result

ITEMS	DETAILS	RESULTS
Storage test	90deg/80%RH for 200Hr	Pass
Temperature/Humidity cycle	10 cycles of 12 hrs for 10deg/44%RH & 60deg80%RH	Pass
Heat cycle	30 cycles of 1 hr for -30deg&+70deg	Pass
Low temperature	-40deg for 200 hrs	Pass
Aging test	70deg/80%RH for 168hrs	Pass
Surface scratch durability	Write and read test after Tabor abrasion on the incident surface.	Pass
Disc dropping	Drop the disc on lauan plate with 1m height.	Pass
Disc bending	Bend disc outer edge with angle of 150 deg for 50 cycles.	Pass
Hydrogen sulfide gas	Exposure in 50deg for 72 hrs in Hydrogen sulfide gas.	Pass
UV light irradiation	Irradiation 7.68+E7J/m <sup>2</sup> (>100 years under office fluorescent light)	Pass
Continuous read stability	Read 1 million times on same track.	Pass
Water immersion	Store the disc in water for 2 weeks	Pass

## 4 Durability for dust and scratch on the surface of the disc

### 4.1 Non-contact operation by optical beam

Optical disc is written and read under non-contact operation by focus light so it has high durability for dust and scratch on the surface of the disc. The phenomena is same as camera system that is not affected on the photo quality by dust on the surface of the lenses, Figure 6 shows the characteristics of influence by dust on the surface of the disc. No read error has occurred by dust of less than 9 μm, thanks to effect of optical beam with off-focused condition. Non-contact reading/recording is a big advantage of optical disc reliability that can't be realized by magnetic recording media.

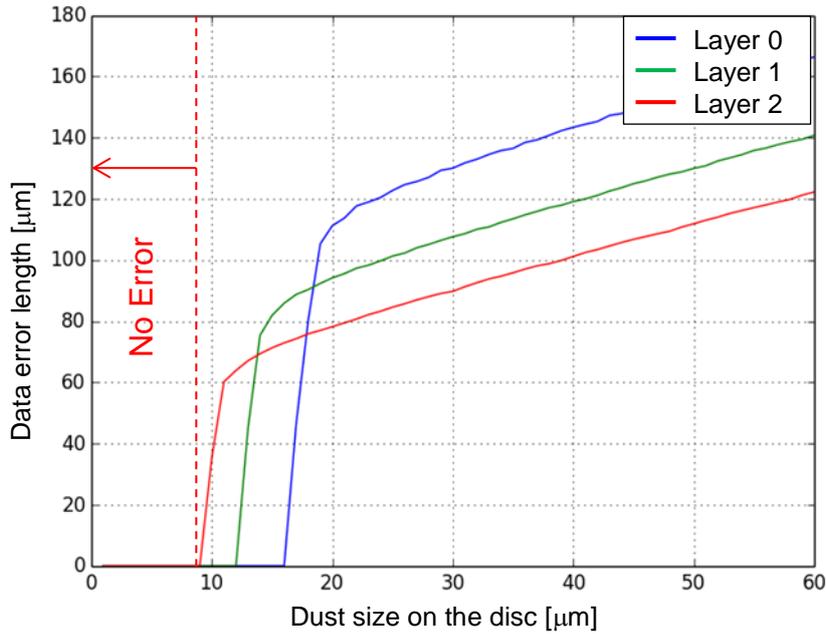


Figure 6 Cross section of the recording layer

#### 4.2 Test result of durability for dust

Panasonic performed accelerated dust test under 270,000 times dense dust condition of class 8 by using the equipment in Figure 7. We installed the freeze-ray expansion module with drive-bay and drive, and fan of the drive-bay was operated for the time that corresponds to continuous operation for 10.4 years in class 8 condition (Class 8 condition is typical data center environment).

#### Dust test equipment

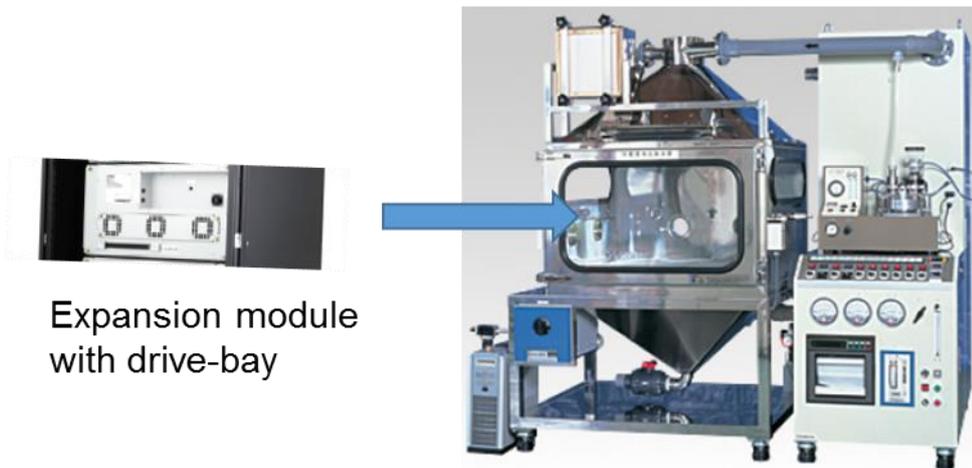


Figure 7 Cross section of the recording layer

After dust acceleration test, we measured the error rate of all area of discs that is installed in the drive during the dust test. The test results are shown in Table 3.

Table 3 Dust test result

Disc Type.	Read Test result
Disc No.1 (Inside the Drive)	Pass (All area of the disc)
Disc No.2 (Inside the magazine)	Pass (All area of the disc)

### 4.3 Durability for scratch

In the 300GB disc specification, the scratch test is specified based on ISO 9352 standard which is composed of tabor abrasion and write/read test. The test is conducted under a very intense condition that results in DVD not being able to be read at all after the scratch test. This is the condition where The surface of DVD disc changed to opaque after the scratch test, however in the 300GB AD disc, data can all be read after the scratch test. Figure 8 shows the surface of the scratched AD disc after the scratch test. The write/read result of the tested disc is shown in Table 4.

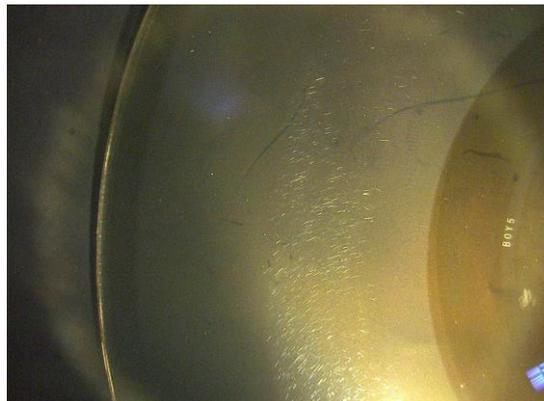


Figure 8 Intentionally scratched disc by tabor abrasion

Table 4 Scratch test result

Test condition	Read Test result
Write test (Radius = 31 – 44mm)	Pass
Read test (Radius = 31 – 44mm)	Pass

### 5 Recycle scheme of discs in Panasonic

Figure 9 shows the recycle scheme of the optical disc in Panasonic. All waste discs are sold to an outer recycle company. In the recycle company, discs are crashed and recording material and UV resin are removed to refine polycarbonate. So discs are recycled in the company as recycled poly-carbonate. Only the recording materials become waste. The amount is 0.012% of total weight.

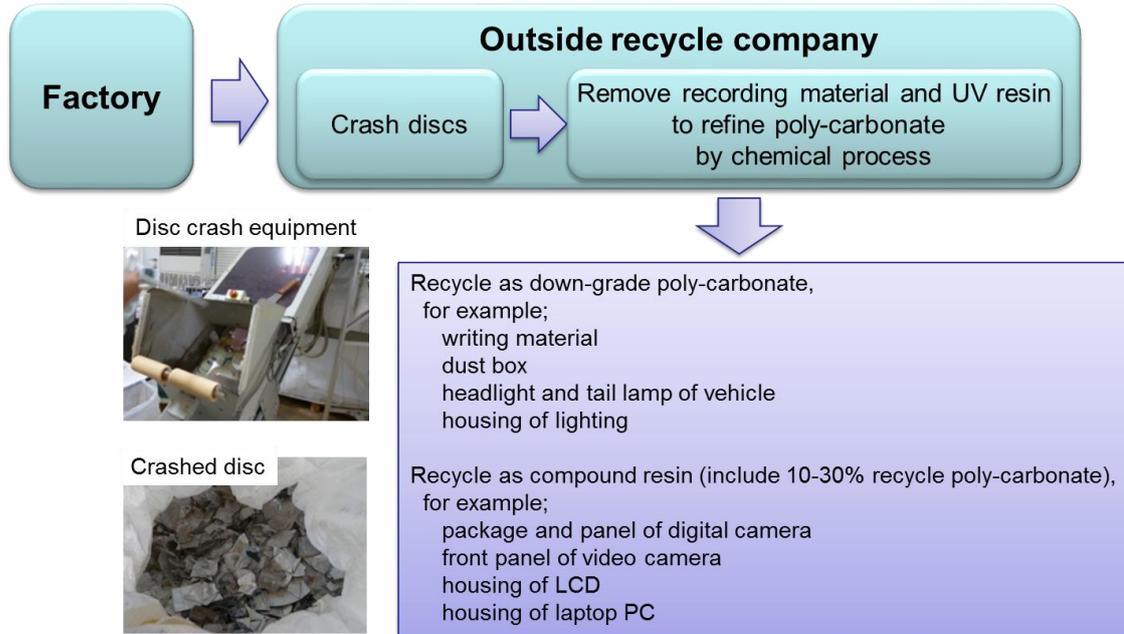


Figure 9 Disc recycle scheme

We estimate that the CO<sub>2</sub> reduction for recycling as shown below. Estimated CO<sub>2</sub> reduction is 84,500kg for waste of 1 million discs. Recycle cost is estimated to be very low because of selling the poly-carbonate waste.

**CO<sub>2</sub> reduction**

	New poly-carbonate	Recycle poly-carbonate
CO <sub>2</sub> emission(kg) / disc (kg)	8.59	1.86

estimated CO<sub>2</sub> reduction is 84,500kg for 1 million discs

\* recycle efficiency is 93%

**Recording materials to be waste**

0.017g/ a disc → 17kg/1 million discs = 300PB