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## **Durability of recordable DVD±R and DVD made of glass (Syylex) at elevated temperature and humidity**

### **Investigation on the preservation of digital archives in the framework of GISDON**

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## **1. PRESENTATION OF THE STUDY**

### **1.1. BACKGROUND**

Optical discs are commonly used for the distribution of works (music, film,...) and for digital archiving. Various studies and especially the French report of the "Academy of Sciences" and the "Academy of technology" called " Longevité de l'information numérique " ("Life-expectancy for digital data") have shown that different media (disk, tape and optical disks) may have lifetimes significantly shorter than those given by the manufacturer. The report recommends looking for other technical solutions for long term preservation of digital data.

Following this recommendation, the group GIS DON (Groupement d'Intérêt Scientifique sur les Disques Optiques Numériques, Group for the Scientific Investigation of optical disks), has requested to verify the temporal stability of the glass DVD, the GlassMasterDisc produced by Syplex.

### **1.2. PURPOSE OF THE STUDY**

This study aims to compare the temporal behavior of GlassMasterDisc with organic and inorganic DVD±R. Thereby, the suitability of this technology for long-term preservation of digital information can be assessed.

To rate the behavior versus time of these discs, their natural aging has to be accelerated. To do this, the DVDs are subjected to harsh climatic conditions concerning temperature and humidity. The degradation of the discs can then be examined after an exposure time of up to 1000 hours. The lifetime of various DVDs under these conditions can then be assessed by measuring the digital errors during the reading of the disc.

### **1.3. PROCEDURE OF THE STUDY**

The behavior versus time of the GlassMasterDisc can be assessed only by comparison. The recordable DVDs, which were used for comparison have either the reputation of having a long lifetime, such as a DVD with an inorganic recording layer, or have in previous studies at LNE shown good results in the accelerated aging test (80°C and 85% RH (relative humidity)).

The DVDs are subjected to the harsh climatic conditions of temperature and humidity above for up to 1000 hours, at 250 hours intervals, in a climate chamber. Since the GlassMasterDisc is made of glass, a temperature of 90°C was chosen, i.e. 10°C higher than in previous studies, whereas the humidity was maintained at 85% RH.

The error rate of the DVDs was measured at the beginning of the study, as well as after each 250 hours in the climate chamber.

The end of lifetime of a DVD is reached when the error rate is higher than the maximum allowed by standards or if the disc is unreadable.

The study was done between 2010 and 2012.

## 2. DVD REFERENCES

### 2.1. RECORDABLE DVDs WITH ORGANIC RECORDING LAYER

Four types of DVDs were chosen due to their good lifetimes shown in previous studies, using the less hard climatic conditions of 80°C and 85% R H. 5 discs of each type were recorded, in order to have the lowest errors rate measured directly after recording.

#### References of DVD+R and DVD-R

No	Trade	Type	Model	Metallic layer	Manufacturer code	Lifetime at 80°C and 85% HR
1	MPO	DVD+R	Gold	gold	MPOMEDIA 0080 (MPO)	1500 h
2	VERBATIM	DVD-R	« Standard »	gold	MCC 03RG20 (Mitsubishi)	1500 h
3	MAXELL	DVD+R	« Standard »	silver	YUDEN000 T03 (Taiyo Yuden)	500 h
4	VERBATIM	DVD-R	Archival Grade	gold and silver	MCC 02RG20 (Mitsubishi)	750 h



***DVD+R MPO GOLD***



***DVD-R VERBATIM***



***DVD-R VERBATIM Archival***



***DVD+R MAXELL***

## 2.2. DVD GLASSMASTERDISC OF SYYLEX

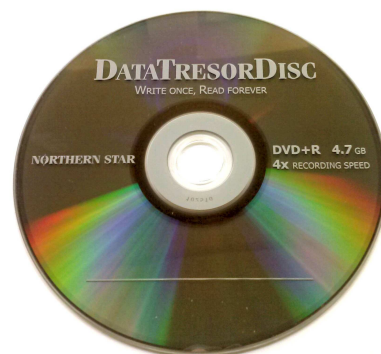
The GlassMasterDisc are produced by engraving the digital information into glass. They are produced by Syylex. 6 samples were studied.



DVD GlassMasterDisc

## 2.3. DVD +R WITH INORGANIC RECORDING LAYER

The two models of discs studied M-DISC (MILLENNIATA) and DataTresorDisc (NORTHERN STAR) are made of a recording layer made of either metal / metal oxide or metal / ceramic.



DVD+R M-DISC (MILLENNIATA)    DVD+R DataTresorDisc (NORTHERN STAR)

Three samples of each model were studied.

## 3. ASSESSMENT OF THE BURNING QUALITY OF THE DVDs

### 3.1. ANALYSIS PARAMETERS

The quality of a DVD is measured as a function of three parameters:

- Measurement of the HF signal (amplitude, contrast und jitter)
- Error measurement (PI8, POF,)
- Servo signals (focus, tracking, ...)

For lifetime assessments only the measurement of errors, and here especially the PI8 error, are taken into account in the standard ECMA 396.

### 3.2. ANALYZERS AND ANALYSIS SPEED

The quality of the DVDs is measured with two types of analyzers:

- An analyzer by Audio Development (CATS DVDR Pro model - software version 3.2 SP1). Besides the error rate, the CATS also provides characteristic information of the HF signal which are received from the optical pickup (optical signal) and servo signals of the focus and tracking signal. This system is a reference system. The test speed is 1X.
- A measuring system from Clover (model DVX with autoloader, version 3.0.7). The Clover system allows measurements (error rates) to 16X test speed.

For each disc, an error rate measurement with the following read speed was performed:

- Cats : 1X
- Clover : 8X

The inorganic DVD + R discs are not readable in the Clover system (compatibility problems with the used Plextor drive). The measurements of these two models were therefore performed with the CATS system only.

### 4. AGING CONDITIONS

The measurement of the aging of recordable discs under normal climatic storage conditions is almost impossible. Due to aging, the degradation of the DVDs is very slow and its observation would take several years. That's why, the behaviour of the DVDs versus time must be made under severe climatic conditions (temperature 90°C, relative humidity 85%). These conditions allow us to accelerate the physical-chemical processes, which are responsible for the deterioration of the discs. The harder the climatic conditions, the higher the acceleration factor is.

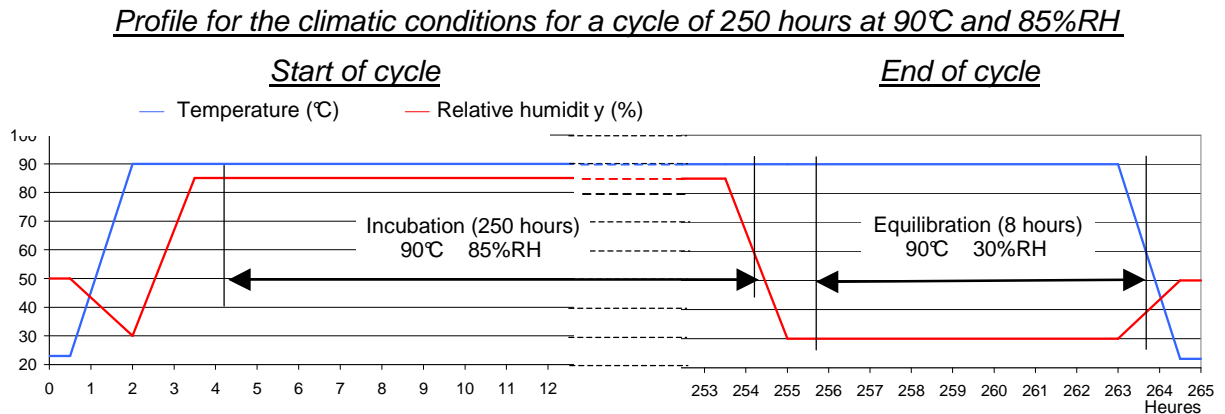
The experiment on accelerated aging was conducted for a total of 1000 hours for the most resistant DVDs, with measurements every 250 hours.

The discs were stored in climate chamber programmable in temperature and humidity : CLIMATS Excal 5423-U.



- DVDs on their support in the climate chamber CLIMATS –

To perform the measurements, the DVDs have to be taken from the cabinet. Therefore, the climatic conditions are gradually returned to normal conditions. To prevent the formation of water droplets in the polycarbonate, it is necessary to "purify" the polycarbonate from the water that was absorbed at high temperature. Therefore the relative humidity is reduced to 30%, while the temperature is still maintained at 90°C. This state, the so-called equilibration state is kept for 8 hours while the temperature remains at 90°C. The following graph shows the temperature and humidity profile during the beginning and the end of a cycle of 250 hours at 90°C and 85%RH.



## 5. RESULTS OF THE EXPERIMENTS ON ACCELERATED AGING

The results are shown below for each type of disc. The end of life of a DVD is defined by reaching one of the following parameters:

- PI8 (averaged over the disc) is greater than 280
- uncorrectable errors POF
- partial or complete unreadability of the DVD

### 5.1. DVD±R

#### DVD+R No 1 from MPO

The error rates increase as a function of exposure time. The errors are uniformly distributed on the disc. After 500 hours the PI8 errors exceed the threshold of 280, and the discs are no longer completely readable. For the still readable discs, the jitter increased from 9% to 10% from T0 to T0+500 hours.

The measured lifetime of the **DVD+R from MPO** is **250 hours**.

#### DVD-R No 2 from Verbatim

After 250 hours of exposure both the error rate and jitter are above their respective thresholds. Several disks are not readable or have uncorrectable errors. This DVD model had the longest lifetime (i.e. 1500h) at 80°C and 85% RH. At 90°C, it is destroyed after the first cycle of 250 hours.

The measured lifetime for the **DVD-R from Verbatim** is **less than 250 hours**.

#### DVD+R No 3 from Maxell

After 250 hours, 4 of the 5 discs were no longer readable.

The measured lifetime of the **DVD+R from Maxell** is **less than 250 hours**.

#### DVD-R No 4 from Verbatim Archival

Only one of the five discs is still readable after 250 hours. In the 4 other discs the averaged PI8 error rate is greater than the threshold of 280, the DC jitter remains below 10%.  
The measured lifetime of **DVD-R Verbatim Archival** is **less than 250 hours**.

### 5.2. DVD GLASSMASTERDISC

All six discs are readable after 1000 hours of exposure. The average error rate PI8 of the discs increased from 4.9 to 6.7 from T0 to T0 +1000 h, the dc-jitter increased from 7.2 to 7.3. There are no uncorrectable errors. The disc has thus practically not changed during 1000 hours at 90°C and 85%RH.

The measured lifetime of the **GlassMasterDisc from Syplex** is **more than 1000 hours**.

### 5.3. INORGANIC DVD+R

#### M-disc

After 250 hours in the climatic chamber, the M-disc exceeds the error rate threshold (PI8). The average PI8 is 870 and the jitter is 11.8%. The discs are unreadable after 500 hours.  
The measured lifetime of the **DVD+R M-DISC** is **less than 250 hours**.

#### DataTresorDisc

After 250 hours, the average error is 161. The dc-jitter is 11.3%. The DataTresorDisc is no longer readable after 500 hours.

The measured lifetime of the **DVD+R DataTresorDisc** is **250 hours**

### 5.4. SUMMARY OF THE TESTS ON ACCELERATED AGING

The following table gives the lifetimes of various DVDs at 90°C and 85% relative humidity:

accelerated aging at 90°C and 85% RH		lifetime (h)				
manufacturer	model	0	250	500	750	1000
MPO	DVD+R Gold					
Verbatim	DVD-R		< 250 h			
Maxell	DVD+R		< 250 h			
Verbatim	DVD-R Archival		< 250 h			>1000
Syplex	GlassMasterDisc					
Millenniaata	DVD+R M-Disc		< 250 h			
Northern Star	DVD+R Data tresor disc					

Among the 7 models of disc examined only the GlassMasterDisc resisted to the accelerated aging at 90°C and 85% relative humidity for 1000 hours. Its PI8 error rates have not increased significantly during the experiment. The lifetime of the GlassMasterDisc is thus in excess of 1000 hours, more than 4 times longer than the best DVD±R (DVD+R MPO and Northern Star).



The DVD + R with inorganic recording layer such as M-DISC and DataTresorDisc show no longer lifetimes than conventional DVD±R.

## **6. CONCLUSION**

The objective of this study was to investigate the behavior of the GlassMasterDisc of Syylex under extreme climatic conditions (90°C and 85% relative humidity) and to demonstrate the potential of this technology for digital archiving. Since there is no absolute reference disc, the DVD GlassMasterDisc has been compared with various other recordable DVD ± R that are on the market.

The result of this study is that the GlassMasterDisc has a much longer lifetime in accelerated aging than other available DVD±R, regardless of whether the latter have an organic or inorganic recording layer. After 1000 hours under extreme climatic conditions, the GlassMasterDisc showed no significant deterioration in quality, while the best conventional disc has a maximum lifetime of 250 hours.

The GlassMasterDisc has therefore the best potential of all recordable DVDs, currently on the market, to create a long-term archive of digital data.

## ATTACHMENT 1: MEASUREMENT PARAMETERS

### Error associated with the readout signals

During readout of a DVD, the HF signal coming from the optical pickup is decoded to generate the digital information. The coding of the signal on the disc is done redundantly to allow for an error correction that corrects the inevitable errors arising in the readout process. The decoding is done in blocks (ECC); these blocks contain 37,856 bytes in 208 lines of 182 bytes. There are two successive levels of error correction:

- correction line by line, if the number of erroneous bytes per line is less than 3
- correction column-wise, if the number of erroneous bytes per column is less than 3.

At 1X DVD speed, a block takes about 0.02 seconds; consequently 42 ECC blocks per second are read.

Two parameters, PI8 and POF, are obtained, which are defined as follows:

<b>PI8</b> <b>(Parity Inner Sum 8)</b>	Number of faulty lines per 8 consecutive ECC blocks, maximum size is 1664. The maximum allowed size is 280. PI8 can be averaged over any desired times (> 0.02 s).
<b>POF</b> <b>(Parity Outer Fails)</b>	Number of defective, uncorrectable (more than 2 bytes wrong) columns per block. The measurement of the total number of POF can extend over any time, even over the entire disc.

The occurrence of POF means a data loss; the error protection is not able to correct the data.

### **Parameters associated with the servo control of the optical pickup**

These parameters are measured only at 1X DVD speed. They are obtained by measuring the servo signals that permit the tracking and focusing of the laser. The following three parameters are measured:

<b>Radial1</b>	<b>Radial deviation (nm)</b> Measurement of the tracking error signal for frequencies below 1,1 kHz
<b>Radial2</b>	<b>Radial deviation (nm)</b> Measurement of the tracking error signal for frequencies for frequencies between 1,1 kHz und 10 kHz
<b>FE</b>	<b>Focus error (μm)</b> Measurement of the focus error signal in vertical direction for frequencies below 10 kHz

### **Parameters related to the intensity and contrast of the HF signal**

These parameters are measured only at 1X DVD speed. The HF signal is modulated by the engraved pits. The length of the pits encodes the digital information. The written marks (pits) and unwritten areas (lands) exist in 10 different lengths which are integer multiples of a fundamental value: 3T, 4T, 5T, 6T, 7T, 8T, 9T, 10T, 11T, 14T. For 1X speed T is equal to 38.2 ns. The modulation of the shortest pits and lands (3T) corresponds to 4.36 MHz; the frequency for the longest symbols (14T) is then 0.93 MHz. Three parameters are measured which characterize the amplitude of the HF signal: R14H, I3/I14, I14/I14H. The measurement system averages these parameters over 1s.

<b>R14H</b>	<b>Reflectivity:</b> Intensity of the reflected light of the 14T lands, in comparison with a standard reflector. The minimum allowed reflectivity is 45%.
<b>I14/I14H</b>	Amplitude modulation of the 14T signals in comparison to the maximum amplitude. The minimum value is 0.6.
<b>I3/I14</b>	Amplitude modulation of the 3T signals compared to the modulation of 14T. The minimum value is 0.15.

The parameter I14/I14H measures the contrast between written areas (pits) and unwritten (lands) zones for longer symbols. The ratio of the 3T and 14T modulation is substantially smaller than 1 because the laser beam of the pickup covers a larger area than that of the 3T.

### Parameters related to the position of the written symbols

Signals for the position and the length of lands and pits are also measured. These parameters are explained in the following table. They are either averaged over 1second (SYM) or 30 seconds (jitter).

<b>ASYM</b>	<b>Asymmetry</b>  The deviation between the mean values of the 3T and 14T signals and the maximum of the HF. Optimal is a slightly positive value. The limits are - 5% to +15%.
<b>DC Jitter</b>	<b>Jitter to clock</b>  The deviation of the position of the zero –crossing of the HF signal to the reference clock, expressed in % of the clock time. The dc-jitter combines on the one hand, the systematic errors associated with the various transitions (e.g. 3T land and 11T Pit) and other random deviations. The maximum allowed value is 9%.

The asymmetry takes negative values if the 3T pits are not well-written and positive values if well written. The parameter depends on the laser intensity at the time of writing. This intensity is normally adjusted during writing in order to achieve an asymmetry value of about 0.

The dc-jitter is sufficiently well coupled with the readout errors because a deviation of a transition of more than 50% from the reference clock causes an error in the decoding.