Family History Archives: Research on New Media

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Introduction

One of the key components of a civilization is its ability to keep records. The records that are the most important to historians and archivists are those that persist, preferably for millennia.

Since the dawn of the digital age, digital records have been notoriously non-persistent, even ephemeral. For example, data stored in the main memory of a computer disappears as soon as the power is turned off. And for decades, there has been no permanent way to store digital information (defining "permanent" to mean at least 500 years under normal conditions). And included in this definition of "permanent" is the implication that active maintenance and migration is completely unviable.

This has led to some very significant concerns about archival of digital information. As reported by Peterson et al. of the 100 Year Archive Task Force: "Digital information is actually easier to lose than if it were on paper or film."[1] Also:

> "The '**two grand technical challenges'** of long term digital information retention are logical and physical migration…. Physical migration means to copy the information to newer storage media to preserve the ability to access it and to protect it from media corruption. Best practices today require logical and physical migration every 3-5 years…. How do organizations expect to do that and keep up with the growth, the cost, and the complexity? The answer is they can not. They will not. It is the contention of the 100 Year Archive Task Force that migration as a discrete long-term preservation methodology is broken in the data center. Today's migration practices do not scale cost-effectively and won't be done until a crisis erupts. This means that today's reliance on migration is taking us down a 'dead-end path'. Hear this clearly. Under these practice guidelines, the world's digital information is at great risk!"[2]

The "great risk" referred to in the last sentence is almost overwhelming. What it means is that, without active management and migration, ALL of today's digital documents that have no paper or film counterpart will completely disappear in 100 years or less. Future historians will refer to these as the digital dark ages[3].

Limitations of Current Options

There are three categories of technology available for storing digital information: magnetic (which includes tape and hard drives), solid state (composed almost exclusively of flash drives), and optical discs (which includes CDs and DVDs and their various flavors). The problems with all these storage options are well known[4,5,6,7,8]. There is fairly wide agreement that none of these options can be relied on for a true archival solution.

Magnetic media is subject to delamination, which is accelerated by high temperatures and high humidity. The bits themselves are subject to demagnetization as a simple function of entropy and the finite coercivity of the media, not to mention accidental exposure to magnetic fields. This demagnetization is also accelerated by high temperatures.

As reported in Lunt, et al., solid state memory cannot be relied on to last longer than 10 years[9]. This is not because the circuits will not last that long, because they probably will. It is due to the nature of how the information is stored as a charge on a capacitor, and all capacitors leak. Once the charge leaks away, the data is lost forever. Again, this is accelerated by high temperatures.

Optical discs suffer from four known degradation mechanisms: delamination, oxidation, corrosion, and dye degradation. Each of these degradation mechanisms is fairly well understood, and each is accelerated by exposure to high temperature and high humidity. Additionally, dye degradation is also accelerated by exposure to light, especially sunlight or artificial sources of ultraviolet light. Current research into the LE (life expectancy) of optical discs varies greatly in their LE predictions, ranging from about 10 years to as many as 300. However, these predictions are for the average LE or for the 95% confidence level LE, which does not tell the user when the first disc is expected to fail.

There appears to be a very wide distribution on this LE parameter, based on experiences with which the authors are familiar. Curators of collections of recordable optical discs, both CD and DVD, tell of discs failing every few years. And this is with discs which are "archival quality", are stored in controlled temperature and humidity environments, and are not circulated! It leaves the individual user with little confidence that ALL of their data will be intact when future generations attempt to access it.

Current State of Research

Current research by Lunt and Linford at BYU and at Millenniata, Inc. (Provo, UT)[10] has been focused on solving the problems described above, and has made very significant progress toward solving all four of the degradation mechanisms.

Recordable optical discs are constructed of four main functional layers, as shown in Figure 1: the polycarbonate substrate (PC), the organic dye, the reflective layer (Ag), and the UV lacquer. There is also a label, but it is not a functional part of the recordable disc.

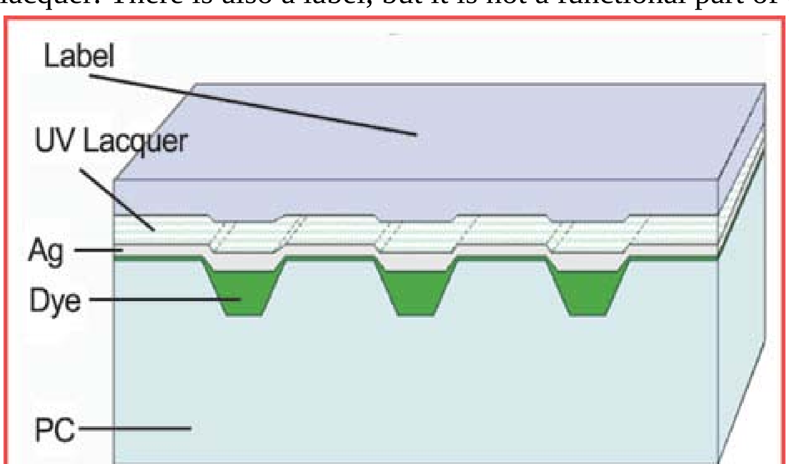

Figure 1: Layers of a recordable CD. [11]

Dye degradation is a very serious problem with today's recordable optical discs. All dyes used are organic in nature, and are necessarily light-sensitive; this means that these dyes will eventually degrade. Our solution has been to eliminate the dye entirely, in favor of a recording material which is impervious to normal light conditions. This is explained in more detail below.

Oxidation and corrosion are failure mechanisms unique to the reflective layer of the disc. In today's recordable optical discs, this reflective layer is made of aluminum, silver, copper, and gold, and various combinations thereof. Gold is used because of its inherent resistance to oxidation and corrosion; the other metals are chosen mainly for their reflectivity at the desired wavelength (650 nm). Our solution has focused on using a reflective recording layer (Data Recording Layer 2 in Figure 2) which is encased in hard, rock-like material (Data Recording Layer 1 & 3 in Figure 2); this sandwich effectively prevents intrusion by foreign matter and has shown itself to be unaffected by elevated levels of humidity, temperature or full-spectrum light.

The final failure mechanism of delamination has been solved by using a unique type of adhesive for bonding to the second layer (L1) of polycarbonate (see the Adhesive Layer in Figure 2), together with carefully controlled conditions for curing the adhesive.

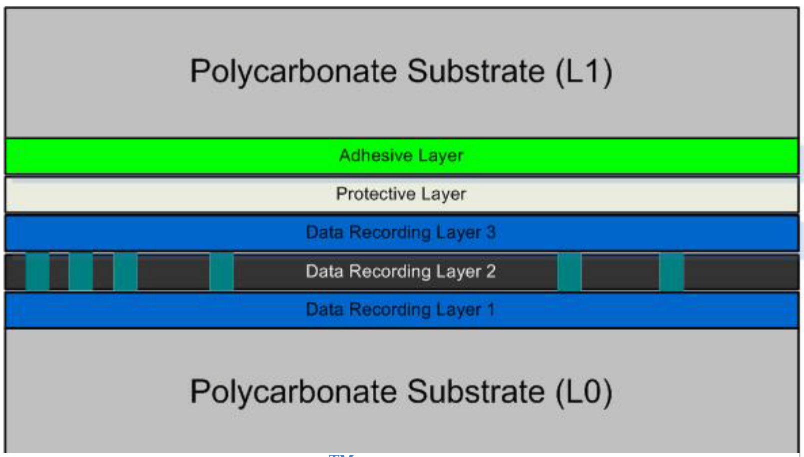

Figure 2: Layers of the M*ARC™ disc. This disc is DVD compatible.

The sandwich shown in Figure 2 has been rigorously tested by being subjected to prolonged exposure to elevated levels of temperature, humidity and light, as well as other types of physical tests. The results of this testing are detailed in the following section.

Testing Results

Among the many topics to be researched during the development of this new media, testing has been a rather significant one. Current tests have included elevated temperature (up to about 85°C), and combined elevated temperature and humidity (up to 85°C/85%RH). These tests have required many weeks and even months to produce predictable results, and this time scale is very impractical when working on testing new media formulations. Accordingly, we have experimented with temperatures up to 120°C, exposure to steam, immersion in water, immersion in hot water (92°C), temperature cycling, and exposure to full-spectrum light. All of these have their respective advantages and disadvantages.

An ideal accelerated test would have several characteristics:

1. Accomplishes the desired accelerated aging in a relatively short time (preferably less than 7 days).
2. Avoids imposing unrealistic conditions on the disc.
3. Can be easily produced and controlled.

Using these characteristics as discriminating criteria, and using uncorrected digital errors as the quantifier for the condition of the discs (errors such as the average and maximum values for PIE8, PIE, PIF, PIF Bytes, and POF), we found that the best type of accelerated test is subjecting the discs to elevated temperature (85°C), elevated humidity (85%RH), and full-spectrum light , all simultaneously, in a photostability/ environmental chamber. This type of test was repeated several times locally and at an independent ISO-certified test facility . It has also been repeated by another independent test facility whose results will soon be published. This test was found to be very effective as measured by all three of the characteristics listed above: the test took only 1 day; the conditions were quite realistic (similar to those of the interior of a car in the sunshine in a Florida summer); and the test has successfully been repeated multiple times at three different test facilities.

A summary of one of these tests is shown in Figure 3. For this test, several DVDs were used from each of four different brands of archival quality DVDs and one brand of a highly-rated standard quality DVD. Also included were several discs of the new media which we have developed.

These discs were all subjected to the same conditions of elevated temperature, humidity and full-spectrum light. Figure 3 shows the trends of the maximum PIE8 error value. It is very significant to note that after only the first period, all five of the commercial discs had already failed the ECMA standard of 280, while the Millennial disc had actually improved.

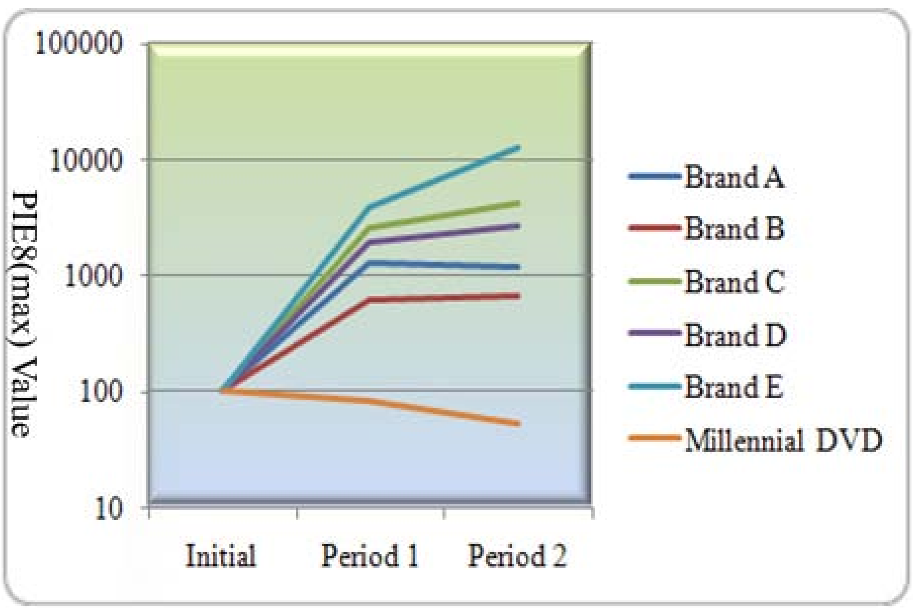

Figure 3: Accelerated testing results for six different brands of DVD.

It should be mentioned here that we do not yet know why our new media would be improving with time. Suffice it to say that the digital errors on our new media did NOT increase at all during this 2-period test, while those on the other DVDs grew substantially.

These discs were also inspected visually after the accelerated testing. For the Millennial discs, there was no visual evidence of any oxidation, corrosion, or delamination. However, some of the other DVDs showed visual evidence of one or more of these degradation mechanisms.

Another version of this same type of test was performed in 2009. In February 2010, Ivan Svrcek of the Naval Air Warfare Center Weapons Division in China Lake, CA[12], released a report of this test which they conducted on six brands of one-time recordable DVDs. Five of these brands are defined by their manufacturers to be “archival-quality” discs; the other brand was a highly reputable disc of normal quality. In this test, many fully-recorded discs from each of the six brands were subjected to elevated conditions of light, temperature and humidity.

The digital errors on these discs were recorded before they were subjected to testing, then again after 24 hours of these elevated test conditions. This cycle was repeated three times with three different groups of discs, to avoid any single-test anomalies.

The results of the test are summarized in the Figure 4 and in the following paragraph:

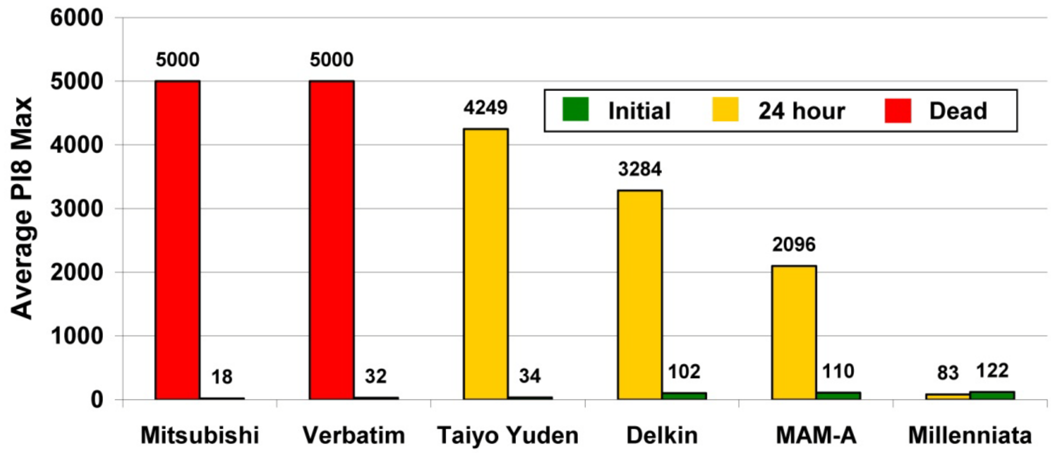

Figure 3-23 PI8 Max Average by Manufacturer Including Dead Discs

Figure 4: Figure 3-23 from page 43 of the Svrcek reference.

> “None of the Millenniata media suffered any data degradation at all. Every other brand tested showed large increases in data errors after the stress period. Many of the discs were so damaged that they could not be recognized as DVDs by the disc analyzer.” (from page i of reference 12).

Recommendations

Based on the above results, we recommend that anyone wishing to choose a media for archival purposes consider subjecting that media to an accelerated test involving elevated levels of temperature, humidity and light, while analyzing the digital errors on the discs periodically.

Also based on the above results, we have strong evidence that we have indeed solved the problems of the four main degradation mechanisms for optical media. We would recommend that this new media be considered for all archival applications, as it would solve the “grand challenge” of physical migration mentioned by Peterson, et al.

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