

apc

HIGH-PERFORMANCE COMPUTING

AUGUST 2005

Digital home invasion

Network your home for PC-based entertainment

INVESTIGATION

DISC ROT

Why data recorded onto optical media can still disappear.



Stop the rot

You've religiously backed up your data to disc. But at the moment of truth, you discover the information is completely unreadable.

Jeanne-Vida Douglas investigates this alarming phenomenon.

What can go wrong

- The bottom layer (substrata) contains the grooves to guide the reading and writing lasers. If it's too thin, the disc warps, increasing jitter and affecting data integrity.
- The organic dye layer containing the data is adversely affected by heat, light and moisture.
- The reflective layer consists of a fine lamina of silver, gold, or a mixture of the two. While both metals perform well initially, silver can oxidise, making it impossible for data to be read.
- Discs are encased in epoxy resin. The almost finished medium is then spun at high speed. If poorly handled, cracks can appear in the resin, allowing moisture and air to come in contact with the reflective layer, speeding up the oxidation process.

While researching his Doctorate of Philosophy on hierarchical intelligent systems at the University of Melbourne, Waratt Rattasiri began regularly backing up his data to recordable CD to guard against hard disk failure leaving him without access to his precious figures. But from the outset, Rattasiri experienced problems recording to the media.

"Sometimes, especially with cheap media, the burning process just stopped," he says. "I knew it was because of the media, not the PC, [since] it would work sometimes if I put in a different brand [of disc]. At other times, after I had successfully burned some cheap CDs, which were readable at that time [and] kept them in my CD book, they just became unreadable for no reason."

Sydneysider Zacha Rosen uses CD-R to archive graphics works, make his own music compilations, and record oral histories from his grandmother, which he records on MiniDisc and backs up on CD.

"It's very important material to me," says Rosen. "So I looked up how to store the CDs properly so that I still have access to it all in case something happens to the original."

Whatever form it takes, information stored on optical media is contained in a layer of organic dye trapped between a thin layer of reflective metal, and a substrata layer etched with a spiral groove just 0.5 microns wide (a single strand of hair is approximately 20 microns thick). Guided by the grooves, disc writers burn pockmarks into the

dye, thus capturing the digital information. When read by a CD player or drive, the pockmarks absorb the laser beam. The unburned areas allow the laser to pass through to the reflective layer, recreating the digital signal.

Similarly, recordable DVD technology relies on a reflective surface and a dye layer into which the data is burned. However, the tracks on a DVD±R are much closer together and the pockmarks burned into the dye are half the size of those on a CD. Due to the added complexity and finer resolution, more can go wrong in the writing and reading process and subsequent performance.

DON'T BELIEVE THE HYPE

Sales of recordable CDs hit the billion per year mark at the turn of the century and have continued to grow — market research group Understanding and Solutions currently estimates CD-R sales at just under 10 billion units annually. Between burn failure and media degradation, however, consumers could just as easily have picked up 9 billion coasters.

With 30 or so manufacturers vying for attention in a white-hot market, hyperbole often wins out in marketing material. TDK claims its entire CD-R range is "manufactured to last a lifetime". Verbatim says its DataLifePlus discs carry a lifetime warranty, promising 100 years of archival stability. Pringo describes its CD-R media as ideal for library storage and personal medical records. But those who have burned and been burned know better.

"Advertising is never trustworthy since all manufacturers say their products are reliable and better than those of their competitors," Rattasiri believes. "Now I rely on word of mouth, Web forums

or a shop's recommendation, not on what the manufacturer says about the product."

TESTING TIMES

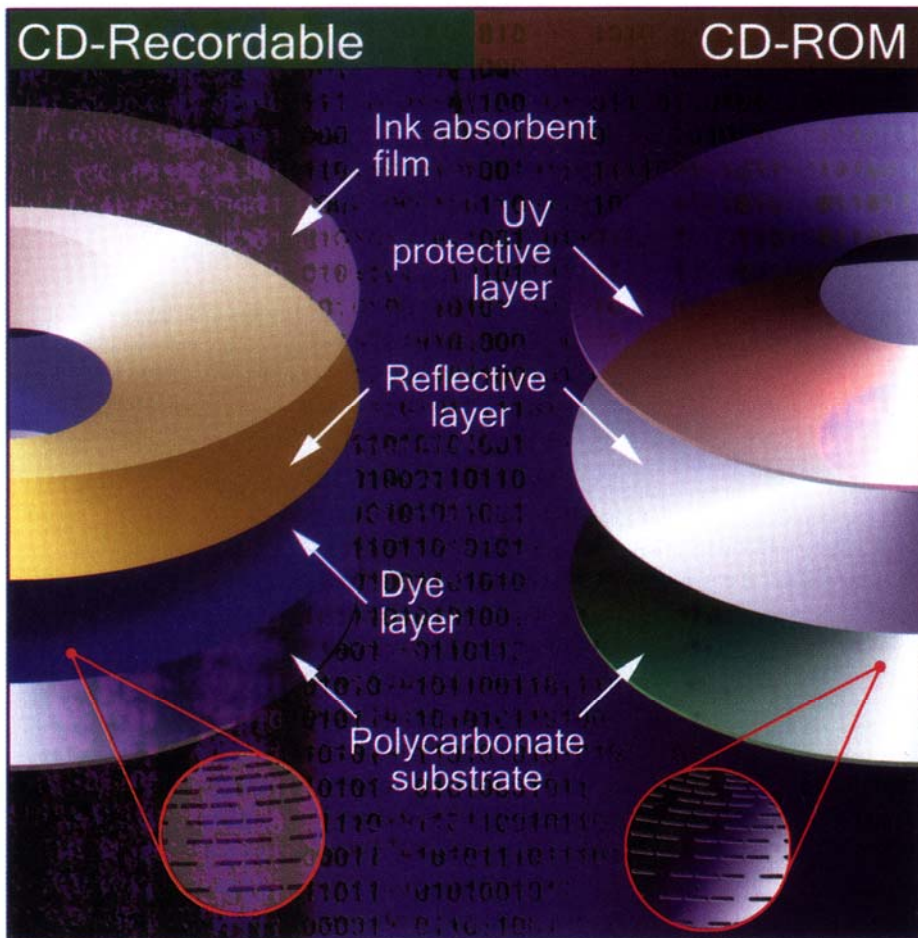
Alerted to the long-term corruption issues associated with optical media, Rosen began testing his older recordings. "Most of them were still okay, but one had a kind of crackling sound — similar to a badly burned CD," he explains. "I was aware of the degradation problems, but I was under the impression I'd been buying good quality media."

Kevin Bradley, manager of the National Library of Australia's Digital Preservation section, says people are surprised when they discover CD-R technology can be an unreliable storage and archiving medium, because it was initially marketed as a "perfect permanent carrier".

"The only way to reliably know the condition of a digital collection is constant and comprehensive testing," insists Bradley. "This can't be stated too strongly — no collection using CD-R as an archival carrier should be without a reliable CD tester."

Most standalone CD and DVD players have built-in error correction systems, which tolerate anywhere up to 220 block errors per second. However, optical drives don't have the same kind of error correcting, so those using CD-R to back up data need to be even more careful about the quality of the media and how it's stored.

The organic dyes used in recordable media have differing levels of stability — data may appear safely archived initially, but can corrupt or even disappear over time. The four



Layer upon layer: recordable media is made up of a combination of protective and absorbent laminas.

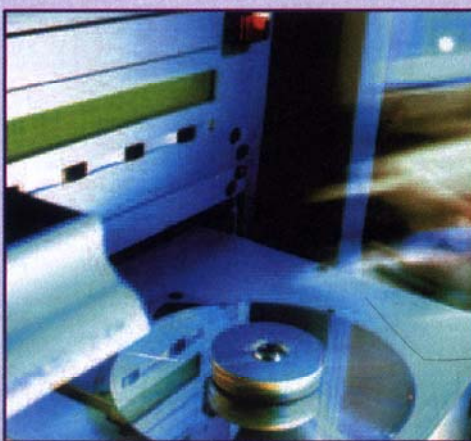
most common dye types (see "Discs tested", page 82) have different structures, but heat, humidity and light all affect the dyes to

differing degrees. Some media will last three years, some may last 300 years. The trick is in choosing the right ones.

Damage control

Investing in a CD CATS analyser is way beyond the budget of most home users, but there are ways to ensure the integrity of data stored on optical media. A Google search returns a plethora of recordable CD and DVD integrity testing applications, and many optical drives come with their own software.

While such programs scan for a range of errors, they are only ever as good as the driver on which they depend, and are only able to test for errors once they have affected the data integrity. And none of these applications are capable of reliably measuring "jitter" — the minute variations in the positioning of the pockmarks burned into the organic dye layer. Although in itself not a fatal



CATS analysers are capable of testing CD-R/RWs that are unwritten, partially or completely written.

error, the presence of high jitter rates indicates the onset of block error, which ultimately renders discs unuseable.

Serious home archivists wanting to get access to a CD CATS analyser can contract companies such as ProDisc, which run high-level tests capable of pointing to integrity problems with the media before any data is lost.

To ensure your data is still around in the long term, use the best quality media. Then make separate copies for access and archiving purposes. Last but not least, store master or archive copies in sturdy, light-proof cases and keep these in a temperature-controlled environment.

After all, if it's worth saving, it's worth saving well.

► Scientists believe that the process of dye destabilisation is accelerated where there are rapid fluctuations in light, ambient temperature and humidity. In one study conducted by the National Institute of Standards Technology in the US, a transparent dye (phthalocyanine) was found to be the most stable. Discs using blue cyanine dye performed well in light tests, but degraded under heat and humidity. Media using dark blue metalised azo dye showed significant losses in all tests.

DO IT YOURSELF

Testing data integrity on home-burned media isn't easy. You need equipment capable of accurately measuring pockmarks 0.5 microns wide and 0.85 microns long, in a dye layer just 0.1 microns thick, resting on a gold or silver reflective layer of about the same thickness. Since the acrylic layer protecting the dye is only 5 microns thick, any minor disturbance to any of these surfaces can result in a reduction in the integrity of the recorded data.

There are software packages available which perform scans through the CD drive, but these are only as good as the drives themselves, and not highly regarded among audio professionals or archivists.

To properly test CD-R media, you need a CD CATS analyser — which cost a prohibitive

US\$80,000. The CD CATS analyser tests data integrity according to 18 parameters, including jitter (the precision of each pockmark); block error rate (BLER), which picks up the number of blocks of data with at least one error; E22 errors, which are only barely correctable; and E32 errors, which simply render the data unreadable.

However, you can test the stability of different dyes at home. Simply take a range of different optical media and burn them all with the same data on the same drive on the same day. Find a nice sunny spot to hang them, then once a week, attempt to retrieve the data. In some cases, you can literally see the dye — and the data — fade away.

WHAT STANDARDS?

With no industry standards for disc quality, and vendors making all sorts of claims, choosing good quality media is a challenge. Bob McAnderson, sales and marketing manager at Grace Information Management, finds the lack of consistency particularly frustrating as his business depends on reliably storing other people's data.

Alarmed at the disparities between, and even within, different brands, McAnderson finally settled on ProDisc, a supplier which can provide a certain degree of quality control, albeit at a higher price.

"Everyone is under the impression that the media is cheap, but it depends on what you're storing. If you save 50 cents per disc but end up losing your archives, you haven't really saved anything," he observes.

At the National Library of Australia, Kevin Bradley has extensively tested CD-R media, but he won't reveal which brands he prefers.

"It's a touchy subject because the archivist wants to say one thing, and the brands want to sell their product," Bradley says. "Even though I know my procedures are fairly accurate, I won't mention the brands."

Cliff Blackburn, an audio engineering consultant working in the film and television industry, is less guarded.

"As soon as CD-Rs began to be mass produced, the failure rate started to rise," Blackburn believes. "[Disc] manufacturers save money wherever they can to push the price down. They use cheaper dyes, cheaper material in the reflective layer and a thinner substrate, so they don't stay flat and you end up with problems in your disc player."

In an attempt to discover the best quality media, Blackburn commissioned a study which tested a series of brands for BLER, reflectivity and E22 errors. And unlike Kevin Bradley, he's happy to share the results (see box "Discs tested", below). **ETC**

Discs tested

Tired of patchy results with CD-R technology, Cliff Blackburn purchased 14 spindles of discs from different brands, gained access to a CD analyser, and put the media through its paces.

Blackburn measured for block error rate (BLER), E22 errors, reflectivity (which should be higher than 65%), and the weighted average window margin (WAWM), which combines 36 timing variables (including jitter) into a single value for rating.

Tests were conducted at the premises of archival disc manufacturer ProDisc using a CD-CATS analyser. Discs were all burned and tested within minutes of each other.

ProDisc managing director David Wickert advises that many brands change manufacturers, factory and production lines frequently, so a bad result in one test of one batch of media doesn't necessarily imply that a brand provides poor quality across the board. However, ProDisc uses only one manufacturer and a consistent "recipe" for its disc production.

Rank	CD-R brand	BLER average	BLER max	E22 max	Reflectivity	WAWM min	Surface colour	Dye type
1	ProDisc Premium White Printable	0.1	13	0	75	38.681	Silver with aqua tint	Phthalocyanine
2	BASF 74 Digital Audio	0.3	10	0	70	37.043	Pale blue	Cyanine
3	ProDisc Dub 80 Utility CD-R	1	25	0	73	37.066	Silver with green/yellowish tint	Modified phthalocyanine
4	That's CD-R 80TY 700MB RV	0.3	12	0	68	32.472	Pale green/blue	Cyanine
5	That's CD-R 80TY 700MB Taiyo Yuden	0.9	19	0	68	30.172	Pale green/blue	Cyanine
6	HHB CD-R74 x1 > x16	0.6	27	2	66	39.95	Silver with green/yellowish tint	Modified phthalocyanine
7	Imation CD-R 700 MB 80 min x1 > x48	2.1	24	5	67	35.357	Silver with green/yellowish tint	Cyanine (unconfirmed)
8	Sony CD-R 700MB Supreme x1 > x40	2.8	26	0	70	34.102	Silver with pale blue/green tint	Cyanine (unconfirmed)
9	EMTEC CD-R 80 x1 > x16	3.5	25	0	67	14.304	Silver with green/yellowish tint	Cyanine (unconfirmed)
10	Laser 80min Premium Gold up to x40	9.3	42	0	68	17.32	Silver with green/yellowish tint	Cyanine (unconfirmed)
11	TDK 74min White Printable x1 > x16	33.2	510	0	69	31.903	Pale blue	Modified cyanine
12	Verbatim CD-R 80 x1 > x24	9.9	53	1	71	20.069	Mid blue	Super azo
13	Sony CD-R 700MB	378.6	100.9	2	67	-3.627	Aqua	Cyanine (unconfirmed)