Recordable CD and DVD for Archiving

When CD-ROM was introduced in 1983, it started a revolution in data storage that is still going on. But it was not until 1992, when the first desktop CD Recorders were shipped, that the real power of compact disc reached consumers. The ability to make on ones own desktop as few as one disc with up to 650 Megabyte of data in a format that was readable on any computer with a CD-ROM drive, made massive data storage and file interchange a reality. That revolution is continuing with the advent of DVD-Recordable in 1998, allowing up to 3.9 Gigabytes on a single disc. In the next year or so, storing the full 4.7 Gigabytes specified in the DVD standards will be possible.

What does this mean for those of us who have large datasets to archive and distribute? Power, reliability and, thanks, to the standards-driven formats, the assurance that we will not have to constantly migrate to newer media just to be able to read our files.

These somewhat broad statements are supported by the facts. Let's start with a discussion of the physical attributes of recordable compact disc media, then discuss data format standards.

Physical Characteristics & Manufacture of CD-Rs & DVD-Rs

The materials used in archive-quality recordable compact discs are extremely stable: polycarbonate, gold, polymer dye and acrylic lacquer. If properly stored and handled, good quality discs that are well-recorded will last for decades, and probably centuries. The catch, of course, is how to be sure that your own discs are good quality and well-recorded. This is not as easy as it should be, but now there is a standard (ANSI IT9.21[1]) that provides guidance for how to test, store, and handle CDs to prevent deterioration of the physical medium to the point of unreadability.

Testing equipment and testing services are available from several companies for those who absolutely must know if their data is properly recorded. For others, who cannot afford either the specialized testing equipment or individual testing by a service, redundancy and periodic re-recording is affordable thanks to the fact that CD-R offers the lowest price per megabyte of any recordable medium available today. Even with adequate testing facilities and well-recorded discs on good media, though, making several copies and storing them in different locations is the best procedure for critical files. Luckily, CD-R media is inexpensive, so this is not a very costly thing to do.

Just what are the optimal conditions for storing and handling compact discs? Stated simply, a normal office environment (perhaps a little cooler than some) is ideal: low humidity, moderate, stable temperatures and filtered light. The conditions that damage discs are high humidity, high temperatures over an extended time (especially when combined with high humidity) or rapid temperature changes, and exposure to broad-bandwidth light that could contain wavelengths that would cause the photosensitive dye layer to decompose.

Recordable Compact Disc Composition

CD-R and DVD-R discs start with an injection-molded, optical-quality polycarbonate substrate, which has a spiraled track pressed into it (properly called a wobbled groove) to ensure compatibility among users. This groove provides a path for the recording laser to follow. On the grooved or data side of the substrate, a polymer dye is applied (it might be either liquid or a film), then the reflective metal (gold or a silver alloy) is sputtered on, and a UV-cured lacquer is spin-coated over the metal to protect it from abrasion. A label, printable or protective surface may be applied over the lacquer, but that is optional.

These materials are individually and in combination very stable. Polycarbonate may over time absorb moisture and become clouded (heat accelerates this process), but if the humidity and temperature are controlled and moderate, that will take a very long time, up to centuries before the substrate is sufficiently clouded to prevent reading by present-day devices. The polymer dye is also chemically stable, although it must be sensitive to certain wavelengths, since that is how the data image is recorded. If the dye is protected from exposure to these wavelengths except during the recording process, the dye could also last for centuries sealed within the disc structure. If the metal layer is 24K gold, the non-corrosable properties of this noble metal ensure that corrosion to the point of unreadability will not occur during the lifetime of the other materials. Other metals are suitable for discs used for applications other than archiving, but should probably be avoided for long-term data storage.

Dr. John van Bogart of the National Media Lab wrote me (see http://www.cd-info.com/CDIC/Industry/news/email-280498.html) that recent tests they have done on CD-ROMs show life expectancies exceeding 100 years, and they are frequently criticized by the industry for being too conservative. Since audio CDs are made with the same materials and using the same procedures (although with less error correction coding), they should last nearly as long. More information on these tests might be available at the NML website (http://www.nml.org), but given the problems they have had with misused materials from their site, maybe not. Read the whole story at http://www.cd-info.com/CDIC/Industry/news/media-problem.html

Hazards to CD & DVD Media

The biggest dangers to discs that are well-made and well-recorded are improper storage and handling. Scratches, even very tiny ones, can accumulate and either allow the metal reflective surface to be interrupted, or occlude the polycarbonate substrate to the point of unreadability, and clouded polycarbonate from high temperature and humidity could prevent reading by a laser beam, which must travel through this layer on the way to and from the reflective surface before reaching the laser pickup sensor in the reader. If the metal layer is missing or corroded, or if the substrate is opaque, or if the dye layer deteriorates and becomes opaque to the reading laser's wavelength (in places where it should be clear), this laser beam will not be reflected back to the reader, and the signal will

not be received by the decoding circuitry. The accumulation of enough of these errors (called BLER or Block Error Rate) will cause the reader's error detection/error correction circuits to reject the disc as unreadable. For more information about BLER and other disc testing issues, please see "Is There a CD-R Media Problem" by this author on The CD Information Center website.[2]

The disc is recorded by burning it with a laser. According to *The Compact Disc Handbook* by Ken Pohlmann:

> The recording mechanism itself may be described as a heat-mode memory. The recording layer is actually a photo-absorbtion surface in that it absorbs energy from the recording laser as heat. Temperature at the focused spot rises above 250 degrees centigrade. This causes the substrate layer to expand into the absorption layer and mix with the dye materials there. Together, the polymer mixed with dye decomposed from heat acts to form pits in the substrate. These pits create the change in reflectivity required by standard CD player pickups.[3]

The readout wavelength and power is different from that used to record discs, so there is no danger of a reader inadvertently recording to a disc.

Standards and Data Formats

The question arises of whether these compact discs can be read 10, 25, 50 or 100 years from now. Compact Disc is the first data storage technology to use an industry-wide accepted, open standard, cross-platform data format. If discs are made to meet this standard (or group of standards), they will almost certainly be accessible by future backwards-compatible disc readers. Of course, it is also advisable to use standard file formats that are likely to be supported, as well as following the disc data formats. Operating systems and programs change much more rapidly than disc data standards, which should be kept in mind when making archive discs for long-term storage.

The compact disc industry has recognized the importance of disc format standards, and at least today is committed to maintaining such backwards compatibility. Like anything else in this world, that could change but right now it looks good. To help maintain that commitment by the industry, concerned users of the technology should become aware of trends in the CD industry, participate on standards committees, and let the manufacturers know about their desire for backwards compatibility. They do listen. This was made evident when DVD was first proposed to use a format not backwards compatible with CD-ROM or CD-Recordable. Users and commentators raised their voices and told the industry this would be an important factor affecting eventual acceptance of the new technology. Now, the MultiRead format has been developed and accepted by 98% of DVD-ROM equipment manufacturers, ensuring that most 3rd generation and later readers can access data on CD-ROM, CD-Audio, CD-Recordable and CD-Rewritable discs as well as on DVD media.[4]

Another development of interest during the transition period from CD-ROM and DVD-ROM is the fact that image files formatted with the DVD-ROM standard can be recorded and used on CD-R and hard disks as well as on the more costly DVD-R media. This means that for data up to 650 MB, CD-R media can still be used, and with the backwards compatibility discussed above, will not require migration to DVD-R media just to be usable with DVD-ROM readers. Of course, these DVD images can only be read by DVD-ROM drives, but there are good reasons to use the DVD format rather than earlier CD-ROM standards: compatibility across platforms is much better than under the older formats.

According to Mark Ely, in *Publishing in the Age of DVD:*

> Following the recommendations of the Hollywood advisory committee, the DVD Consortium included specific audio and video formats as well as interactive functions into the DVD 1.0 specification. This is a major advantage that DVD maintains over CD-ROM. In CD-ROM there is no single specification for audio, video, or a file system. This has led many multimedia developers to invent their own audio/video formats for delivering interactive content. Unfortunately, there is no guarantee that content authored and developed for one configuration of a CD-ROM equipped computer will work with other models. Since DVD has specific audio format, video formats, and a file system, content authored for DVD has the advantage of cross-platform compatibility.[5]

More information about DVD and DVD-ROM can be found in *Jim Taylors DVD FAQ*[6] and other web sites. A list of DVD related websites is available from *The CD In formation Center* website as well.[7]

Conclusions

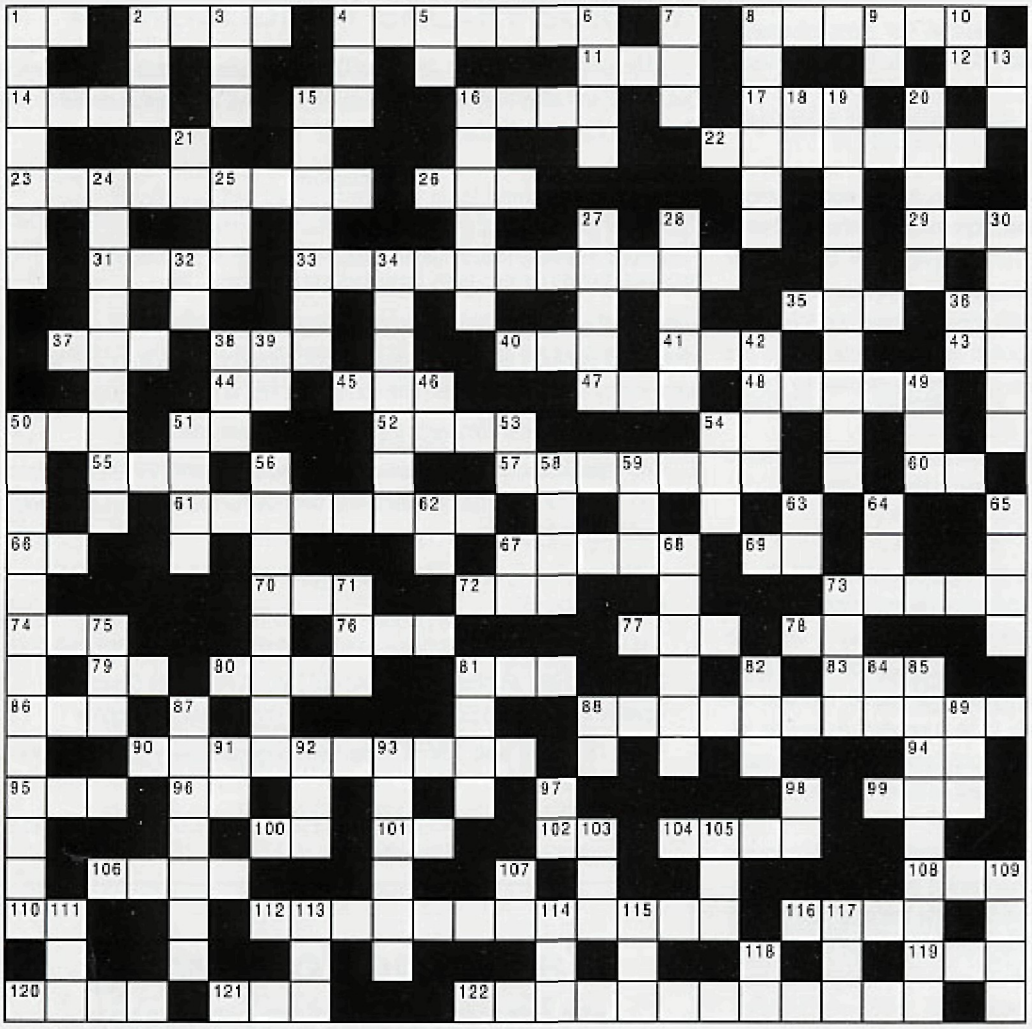
Reliable, long-lived media and industry-wide standards, combined with affordable prices and large storage capacity, make recordable CD-ROM and DVD-ROM excellent choices for long-term, large data set archiving. ■

Katherine Cochrane is president of The CD-Info Company, Inc., publisher of information products about the Compact Disc industry, technology and applications. <http://www.cd-info.com> She can be reached at katherine@cd-info.com

1. American National Standards Institute, <http://www.ansi.org>
2. Cochrane, Katherine W. Is there a CD-R Media Problem? On *the CD Information Center. <http://www.cd-info.com/CDIC/Technology/CD-R/Media/problem.html>*
3. Pohlmann, Ken C. 1992. *The Compact Disc Handbook.* 2nd ed. A-R Editions Inc., Madison, WI
4. The Optical Storage Technology Association website <htrp://www.osta.org>
5. Ely, Mark. 1998. *Publishing in the Age of DVD: A Primer for Creating Content for DVD.* 3rd Ed. Sonic Solutions. <http://www.sonic.com>
6. Video Discovery web site at <http://www.videodiscovery.com/vdyweb/dvd/dvdfaq.html>
7. Cochrane, Katherine. DVD Information Page in *The CD Information Center,* 1998. <http://www.cd-info.com/dvd/>

IC and Computer Terminology

Mary Alexander, Judy Murphy & Pat Deshaye



ACROSS

1 Refers to 2.88 M floppy disks or extra high density.
2. Changes electron flow in transistor.
4. Material drifted in EDS detector crystal to prevent current loss.
8. A machine or tool.
11. Interdiffused multilayer process, acr.
12. A million bytes, acr.
14. Complementary metal oxide semiconductor. acr.
15. Wafer material.
16. What a Peltier device does.
17. Internet protocol used by electronic mail program to download messages from mail server, acr.
22. Microwire.
23. Increases signal.
26. Infra-red microscopy.
29. Electrostatic discharge, acr.
31. Top layer.
33. Insulating layer.
35. Standard unit describing one volt divided by one amp.
36. Manipulating images, acr.
37. Wire Bond site.
38. Organization that adds value to a system and resells it, acr.
40. Interface between networks, acr.
41. Measurement unit for resistance.
43. Leading semiconductor mfgr. founded in 1930 as Geophysical Service, Inc., acr.
44. Current that is not alternating, acr.
45. Connection between layers of IC pathways.
47. Aluminum is a ____-ferrous metal.
48. Field of transistors.
50. Small-scale integration.
51. A proprietary high-speed bus used in the VAX series.
52. Item common to IC's, potatoes and poker.
54. Same as 91 Down.
55. An IBM mainframe protocol that allows two JES devices to communicate with each other.
57. Block of pure silicon.
60. One billion bytes, acr.
61. Pathway material.
66. SEM imaging mode based on photons, acr.
67. Implant on surface during doping.
69. SEM imaging mode using voltage information, acr.
70. Chemical vapor deposition, acr.
72. Specific device technology utilizing sapphire, acr.
73. Electronic value.
74. A microscope using a gallium ion source.
76. Type of hardware interface used to connect hard disks to PC, acr.
77. Packaged chip.
78. First company to commercialize the silicon transistor, pocket radio, IC, hand-held calculator, single-chip computer & LISP chip, acr.
79. Use of CD-ROM & videodisc controlled by computer for an interactive activity, acr.
80. ___ wire is used to connect chips to lead frame.
81. Plastic encapsulated device, acr.
83. Computer assisted design, acr.
86. Cathode ray tube, acr.
88. Placed on wafer for photolithography.
90. Electronic switch.
94. Study of faults, acr.
95. E. Ruska associated with this microscope, acr.
96. IBM mainframe 4GL that runs under MVS. Originally designed for non-computer people, acr.
99. Microscope which resolves at atomic level, acr.
100. Master control program that runs computer, acr.
101. Electromagnetic frequencies above audio and below visible light.
102. One one-thousandth of a volt, abbrev.
104. Single in-line memory module, acr.
106. Electron beam induced current.
108. Scanning acoustic microscopy.
110. Sodium.
112. Top layers of clear insulating material on IC chips.
116. Very large scale integration, acr.
119. Lubricant.
120. Microscope for multilayer inspection.
121. Used as sensor in flat-bed scanners, acr.
122. A "peeling away".

DOWN

1. Removes unwanted deposited material.
2. Alternative to Si.
3. Organization that sets telecommunications standards worldwide, acr.
4. Integration between 3,000-100,000 transistors on chip, acr.
5. Can-type package for discrete device, acr.
6. Very old term for processor (number crunching).
7. Postscript file format, acr.
8. Boron, for example.
9. Integrated circuit, acr.
10. Width of one numeric digit.
13. Communications carrier that provides services in Great Britain & Northern Ireland, acr.
15. Aligns wafer with mask.
16. Ceramic dual-in-line package, acr.
18. Technology using objects, acr.
19 N-type dopant.
20. Slice of Silicon.
21. Symbol for ratio of circumference of circle to its diameter, acr.
24. Protective cover for chip.
25. Field effect transistor, acr.
27. IC etchants.
28. P-type dopant.
30. Applying boron.
32. IBM's first 286-based PC, introduced in 1984.
34. Substrate for electronic elements.
36. Formal title for data processing, MIS, or IS dept. Same as Information Systems, acr.
38. Intel standard for speeding up full-motion video performance, acr.
39. Common form of electricity from power plant to home whose direction is reversed 60 times per second in U.S.
42. Logic pattern on glass.
46. "___ha!" exclaimed the FIB operator.
49. Crystal sensor for CCD, acr.
50. Detailed description of requirements.
51. Cross sectional view of gate called a "birds___."
53. Acid/base measure.
54. Open standard based on UNIX and Windows NT to provide users a migration path from x86 PCs to MIPS RISC machines, no longer used, acr.
56. Electronic element interface.
58. Bump on pathway.
59. Communication satellite that orbits no higher than 500 miles above the earth, acr.
62. Combination of menus, screen design, keyboard commands, command language and help screens, which create the way a user interacts with a computer, acr.
63. Electrical current that travels in one direction; used within computer's electronic circuits, acr.
64. Silicon-on-insulator, a device technology, acr.
65. Si crystal from which ingots are grown.
67. On/off switches often labelled this.
68. Polishing device for IC cross sections.
71. Singular of "dice".
73. Die, plural.
75. Valued at 0 or 1.
81. Programmable read-only memory.
82. Failure mechanism, acr.
84. Arsenic, acr.
85. Doping process.
87. Minute cracks in the glassivation.
88. Computers that conform to the standard originally developed by IBM, acr.
89. Microscope based on sound.
91. IBM mainframe 4GL that runs under MVS. Originally designed for non-computer people.
92. Silicon-on-sapphire, acr.
93. Cause of delamination and other failures.
97. 1 times 10 to the eighteenth power, acr.
98. Optical microscope, acr.
103. Computer screen.
105. A charged atom.
107. Millivolt.
109. Ion___; a micromachining device.
111. Type of scanning probe microscope, acr.
113. Lit-up display, acr.
114. One of largest commercial on-line service providers, acr.
115. Started out as Computing-Tabulating-Recording Co. in 1911, acr.
117. Number of lines printed in a vertical inch, acr.
118. Program to know, explain, and defend results, acr.

Reprinted from the Delta Microscopy Newsletter, Volume 12-1, February 1998