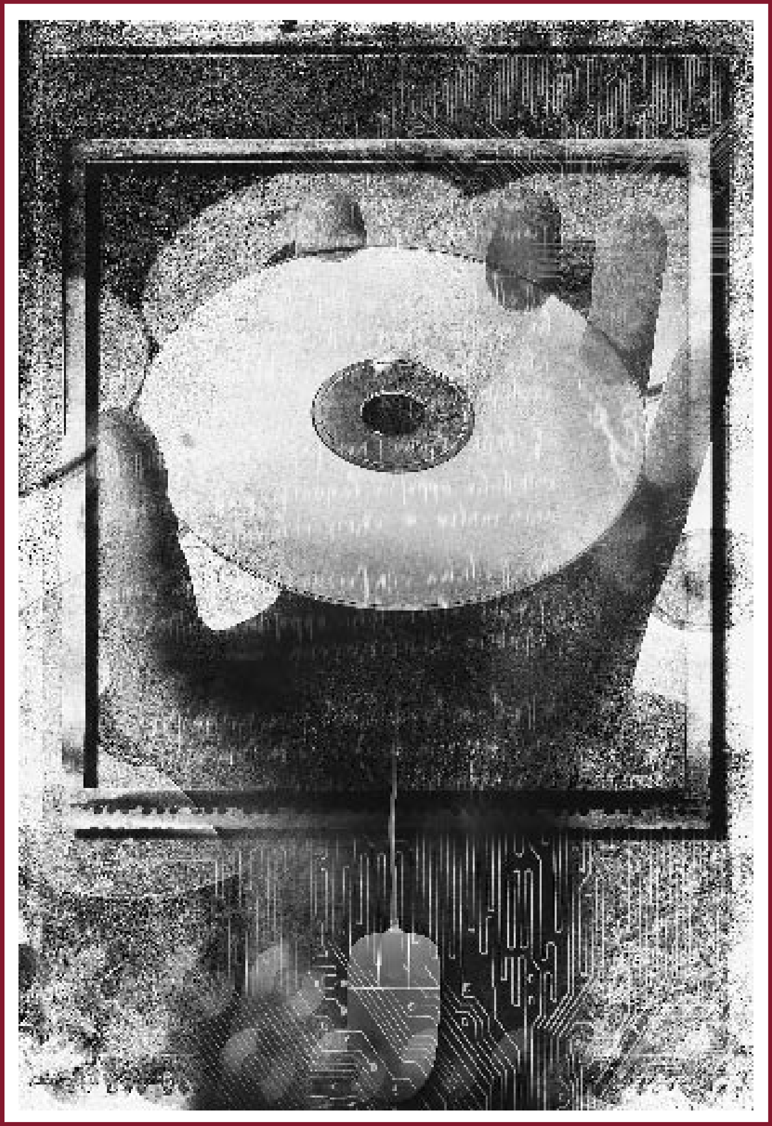
A GUIDE FOR LIBRARIANS AND ARCHIVISTS

Care and Handling of CDs and DVDs



by Fred R. Byers, October 2003

Council on Library and Information Resources
National Institute of Standards and Technology

Care and Handling of CDs and DVDs

A Guide for Librarians and Archivists

by Fred R. Byers

October 2003

Council on Library and Information Resources
Washington, DC

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

About the Author

Fred R. Byers has been a member of the technical staff in the Convergent Information Systems Division of the Information Technology Laboratory at the National Institute of Standards and Technology (NIST) for more than six years. He works with the Data Preservation Group on optical disc reliability studies; previously, he worked on the localization of defects in optical discs. Mr. Byers' background includes training in electronics, chemical engineering, and computer science. His latest interest is in the management of technology: he is currently attending the University of Pennsylvania and expects to receive his Executive Master's in Technology Management (EMTM) degree in 2005.

Council on Library and Information Resources

The Council on Library and Information Resources is an independent, nonprofit organization dedicated to improving the management of information for research, teaching, and learning. CLIR works to expand access to information, however recorded and preserved, as a public good.

National Institute of Standards and Technology

Founded in 1901, the National Institute of Standards and Technology is a nonregulatory federal agency within the Technology Administration of the U.S. Department of Commerce. Its mission is to develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life.

The Information Technology Laboratory within the National Institute of Standards and Technology works with industry, research, and government organizations to make information technology more usable, secure, scalable, and interoperable than it is today. It develops the tests and test methods that developers and users of such technology need to objectively measure, compare, and improve their systems.

The Convergent Information Systems Division develops and promotes the exchange, storage, and manifestation of digital content via information technology standards, measurements, and technology that support the economy, welfare, and defense of the United States.

ISBN 1-932326-04-9

Copublished by:

Council on Library and Information Resources
1755 Massachusetts Avenue, NW, Suite 500
Washington, DC 20036
Web site at http://www.clir.org

and

National Institute of Standards and Technology
100 Bureau Drive
Gaithersburg, MD 20899
Web site at http://www.itl.nist.gov

Additional copies are available for $15 per copy. Orders must be placed through CLIR's Web site.

The paper in this publication meets the minimum requirements of the American National Standard for Information Sciences—Permanence of Paper for Printed Library Materials ANSI Z39.48-1984.

Contents

Tables

Figures

Author's Acknowledgments

I would like to acknowledge the people who helped make this document possible. Contributions came from within the Convergent Information Systems Division at NIST, most notably and with major input from Jian Zheng and Richang Lu.

I would like to acknowledge, in particular, Jian Zheng, for his technical advice and unending enthusiasm in support of this effort. With his extensive background in optical disc manufacturing and research, he provided invaluable insight into the complexities of these discs and issues related to their usage.

Other major input from the Division came from Oliver Slattery, Gordon Lyon, Joe Navarro, and Dr. Victor McCrary. I would like to give a special thanks to Dr. Xiao Tang for suggesting this work and for providing the opportunity to assemble the information in this document, and to Paul Vassallo for his wisdom and guidance.

Others to whom I am deeply indebted for their excellent suggestions are: Janet Gertz, director for preservation, Columbia University Libraries; Christie Stephenson, director, Digital Conversion Services, University of Michigan Library; Melinda Baumann, director, Digital Library Production Services, University of Virginia Library; Catherine Murray-Rust, associate university librarian, Oregon State University; Samuel S. Brylawski, head, Recorded Sound Section, Motion Picture, Broadcasting and Recorded Sound Division, Library of Congress; Linda Tadic, director of operations, ArtSTOR, The Andrew W. Mellon Foundation; William T. Murphy, president, AVArchives Services; Ed H. Zwaneveld, innovation strategist/coach and archival system architect, INNOVAID-E; and Jim Wheeler, Tape Restoration & Archival Services.

Finally, NIST thanks the Council on Library and Information Resources, particularly Deanna Marcum, Kathlin Smith, and Amy Friedlander, for their patience and constant support from the inception of this project to the final distribution of this document. They provided much insight and cooperation on this team effort.

Fred Byers

Quick Reference Guide for Care and Handling

Do:

1. Handle discs by the outer edge or the center hole.
2. Use a non-solvent-based felt-tip permanent marker to mark the label side of the disc.
3. Keep dirt or other foreign matter from the disc.
4. Store discs upright (book style) in plastic cases specified for CDs and DVDs.
5. Return discs to storage cases immediately after use.
6. Leave discs in their packaging (or cases) to minimize the effects of environmental changes.
7. Open a recordable disc package only when you are ready to record data on that disc.
8. Store discs in a cool, dry, dark environment in which the air is clean.
9. Remove dirt, foreign material, fingerprints, smudges, and liquids by wiping with a clean cotton fabric in a straight line from the center of the disc toward the outer edge.
10. Use CD/DVD-cleaning detergent, isopropyl alcohol, or methanol to remove stubborn dirt or material.
11. Check the disc surface before recording.

Do not:

1. Touch the surface of the disc.
2. Bend the disc.
3. Use adhesive labels.
4. Store discs horizontally for a long time (years).
5. Open a recordable optical disc package if you are not ready to record.
6. Expose discs to extreme heat or high humidity.
7. Expose discs to extremely rapid temperature or humidity changes.
8. Expose recordable discs to prolonged sunlight or other sources of ultraviolet light.
9. Write or mark in the data area of the disc (the area the laser “reads”).
10. Clean by wiping in a direction going around the disc.

For CDs especially do not:

1. Scratch the label side of the disc.
2. Use a pen, pencil, or fine-tip marker to write on the disc.
3. Write on the disc with markers that contain solvents.
4. Try to peel off or reposition a label.

General recommendations for long-term storage conditions:

For archiving recordable (R) discs, it is recommended to use discs that have a gold metal reflective layer.

Archival Storage Facility—Recommendation for storing CDs and DVDs together

Media	Temperature	Relative Humidity (RH)
CD, DVD	Less than 20°C (68°F) Greater than 4°C (39°F)	20% to 50% RH

A temperature of 18°C and 40% RH would be considered suitable for long-term storage.
A lower temperature and RH is recommended for extended-term storage.

I. Introduction

1.1 Scope of This Guide

This document describes methods for the care and handling of optical discs and is intended for use by librarians and archivists in government, academia, and industry. It draws on accumulated industry knowledge and the results of specific studies by the National Institute of Standards and Technology (NIST).

The document provides guidance on how to maximize the lifetime and usefulness of optical discs, specifically CD and DVD media, by minimizing chances of information loss caused by environmental influences or physical handling. Discrete topic areas include prevention of premature degradation, prevention of information loss, CD and DVD structure, disc life expectancy, and conditions that affect optical discs. Other issues relevant to the management or maintenance of optical systems are beyond the scope of this document. Excluded, for example, are such topics as care and maintenance of the disc drive device and associated hardware and software; digital rights and related legal questions; and methods of making, sending, and receiving digital copies, including analog-digital conversion procedures.

This document is intended neither to represent nor imply a standard. It is merely a consensus of several reliable sources on the prudent care of CDs and DVDs.

1.2 Use of Terms: Information, Content, and Data

Information and *content* as used throughout this document refer to audio, video, photographic images, graphics, animations, interactive games, computer applications, documents, files or data, and any other digital objects. *Data* refers to the small pieces of information from which "understandable information" is derived. The term is used extensively in this guide to refer to the bits recorded in the disc. Such bits, or data, are interpreted as ones and zeros by the optical disc drive. Eventually, through a series of manipulations by the hardware and software of a computer or playback system, these bits become "information," in any of its fully interpreted forms, for the user.

1.3 Comparative Stability of Optical Discs and Other Media

Among the digital media, prerecorded and write-once optical discs are more stable than digital magnetic tape. Neither optical discs nor magnetic tape, however, is as stable as microfilm or paper. With proper care, microfilm and non-acidic paper can last for centuries, while magnetic tape lasts only a few decades (Van Bogart 1995). Just as film types can vary in years of usefulness, one disc type can also last longer than another. Temperature and humidity conditions can markedly affect the useful life of a disc; extreme environmental factors can render discs useless in as little as a few days.

Media deterioration is but one aspect of the preservation challenge. A potentially more immediate threat is technological obsolescence. Technological advances will no doubt make current optical disc types obsolete within several years. If the software currently used to interpret the data on optical discs becomes unavailable, a migration or emulation technology will be needed to access the data. Also, if the current disc-drive technology becomes unavailable, and if disc drives produced in the future lack the backward compatibility to play today's discs, the information on the discs will likewise be inaccessible. Film and paper are much more stable in this regard, as human language does not change as rapidly as computer software, hardware, or the media format. "Ink on paper," for example, has been used for centuries, and film has not changed significantly over the years.

The importance of ensuring that information can be read by future generations cannot be overstated. It is vital to have in place a preservation strategy that guarantees the sustainability of the collection for as long as possible. The computer-user "industry standard" for data storage on removable digital media has changed considerably over the past few decades (TASI 2002). As shown in Figure 1, digital media used as recently as 20 years ago are already incompatible with most of today's systems.

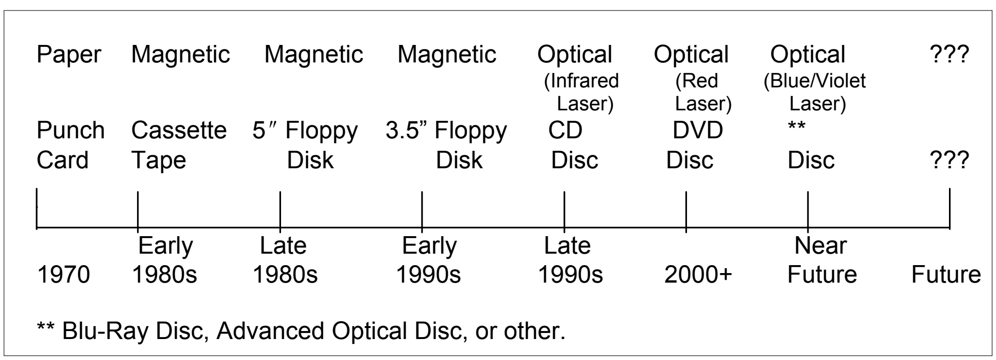


Figure 1: User removable storage-media timeline
Timeline illustrates the changes in common "removable" storage media (Technical Advisory Service for Images (TASI) 2002, extended by author)

1.4 CDs and DVDs: Operation and Variety

CD is short for compact disc. DVD initially stood for *digital video disc*, then *digital versatile disc*, but today the term *DVD* is often used without referring to a specific set of words. Both CDs and DVDs are optical media, meaning media that use light technology (more specifically, laser light) for data retrieval. A disc drive focuses a laser light beam into the CD or DVD to "read" the bits (data) in the disc. The drive can also "write" bits by focusing the laser beam into recordable CDs or DVDs. The laser reads and writes data starting from the center of the disc and proceeding in a spiral direction toward the outer edge. A pre-groove is stamped in all blank recordable and rewritable CDs and DVDs to guide the laser as it writes.

Optical discs are differentially identified to designate specific features such as recordability, rewritability, and accessibility. For example, CD-R, DVD-R, and DVD+R discs are dye-based recordable (write-once) discs—i.e., recordable but not erasable. CD-RW, DVD-RW, and DVD+RW discs are phase-change based, recordable, (rewritable) discs, or discs that permit the erasing of earlier information and the recording of new material in the same location on the disc. DVD-RAM discs are phase-change based, recordable (rewritable) discs formatted for random access, much like a computer hard drive. CD-ROM and DVD-ROM discs are pressed and molded, nonrecordable, read-only discs. Brief definitions of the various types of optical disks can be found in the glossary; disc structure is covered in greater detail in section 3.

2. Ensuring That Your Digital Content Remains Available

Archivists and librarians place great emphasis on preserving content for the long term while ensuring its everyday usability. One of their major challenges is to ensure continuing availability of the digital content in their collections. Another challenge is to keep the medium of storage in a condition as near as possible to the original until the content is no longer needed or until it is migrated to a newer technology as the medium becomes outdated.

Archiving digital content requires an ongoing technological strategy to ensure access to stored collections over time (Lee et al. 2002). Content that has been converted from analog to digital format must be migrated to, or made accessible by, newer technologies more frequently than is necessary with analog formats. A technological strategy for digital content is increasingly important as more analog content is converted to digital format and as more content is created digitally (born digital). The importance of proper handling of the digital media therefore increases as digital collections grow (NDIIPP 2002).

Digital media have become popular, in part, because content can be accessed and distributed easily and quickly, and because digital media can store the equivalent of reams of documents or hundreds of songs on one tape or disc. Optical discs can provide faster access than magnetic tape to a particular file, song, video clip, document, record, or photograph within collections stored on the medium. These benefits have prompted significant increases in analog-to-digital conversion of existing documents, books, periodicals, photographs, and graphics, as well as music and moving images. CDs and DVDs have become popular formats for the recording and storing of all types of digital content.

There are, however, potential trade-offs in analog-to-digital conversion. The digital version may not exactly represent the analog original because of the effects of sampling rates, compression algorithms, or the quality of recording during the conversion. Losses in fidelity vary in nature and extent, but the possibilities should be considered by anyone involved in an analog-to-digital conversion process.

Digital copies of digital originals, however, maintain the quality of the original, assuming such content has not been altered by system software, hardware, or the condition of the medium. Similarly, digital copies of the first digital copy of an analog original will maintain the quality of that copy. Accordingly, continued digital copying should not compromise the quality of the content recorded from CDs, DVDs, or other digital sources.

The ability to make copies of equal quality (digital-to-digital) means that it is possible—and recommended—to archive one copy of a given digital collection (preferably the original) by storing it in a location separate from that of frequently accessed copies. Presumably, then, the archived (original) media will be needed only for inspection, production of additional copies, or migration to new media. One of the most important benefits of archiving is increased security; it helps prevent information loss caused by disaster, theft, or mishandling.

If budgetary limits preclude separate locations, then multiple copies should be kept at the same location. The original can be designated as "archival," and the copies "accessible." If the original is in analog format, then the analog version and the original digital copy should both be archived. Dual archiving will make both the analog original and the digitally converted copy available for future access and thus minimize the impacts of deterioration. The version least affected by deterioration will become the version of choice for copying. Even where storage facilities do not meet recommended guidelines, the original media must be kept isolated and protected, and only copies thereof used for everyday access.

Archived copy—Limited use	Frequently accessed copy—Multiple use
• Store in a controlled environment and at a separate location, if possible, from the frequently accessed copy. • Store in environmental conditions recommended for archival storage.	• Store for easy access. • Check disc visually for damage or contamination after handling. • Store in environmental conditions similar to usage conditions.

3. Disc Structure

CDs and DVDs consist of the same basic materials and layers but are manufactured differently. A DVD is actually like two thin CDs glued together. A CD is read from and written to (by laser) on one side only; a DVD can be read from or written to on one or both sides, depending on how the disc was manufactured. Recordable DVDs (DVD-R, DVD-RW, DVD-RAM) can be manufactured with one recording layer on each side. Prerecorded DVDs (DVD-ROM) can be manufactured with one or two recorded layers on each side.

3.1 Polycarbonate (Plastic) Substrate Layer

The polycarbonate substrate makes up most of the disc, including the area that is read by the laser (opposite the label side on CDs). It is present on both sides of a DVD, even a "single-sided" disc with a label on one side. This substrate provides the disc depth necessary to maintain laser focus on the metal and data layers. It also gives the disc enough strength to remain flat. Anything in or on the polycarbonate layer that interferes with the ability of the laser to focus on the data layer will result in the misreading of data. Accordingly, fingerprints, smudges, or scratches, as well as such substances as dirt, dust, solvents, and excessive moisture (which polycarbonate will absorb), can interfere with the ability of the laser to read the data. Contact of any foreign material with the polycarbonate substrate layer should be avoided.

3.2 Data Layer

As its name implies, the data layer of CDs and DVDs is the layer that contains the data. The data appear as marks or pits that either absorb light from the laser beam, or transmit the light back to the laser photosensor by way of the metal reflective layer. In CDs, the data and metal layers are very close to the top of the disc (label side); in DVDs, they are in the middle of the disc (see Figures 1–6). The types of data and metal layers used depend on the type of disc—read-only (ROM), write-once (R), or rewritable (RW, RAM). Table 1 shows the relationship between the data and metal layers and the disc type.

CD-	DVD-	Type	Data Layer	Metal Layer
CD-ROM Audio/Video and PC use	DVD-ROM Video/Audio and PC use	Read only	Molded	Aluminum (also silicon, gold, or silver in double layered DVDs)
CD-R	DVD-R DVD+R	Recordable (Write once only)	Organic dye	Gold, silver, or silver alloy
CD-RW	DVD-RW DVD+RW DVD-RAM	Rewritable (Write, erase, and re-write)	Phase-changing metal alloy film	Aluminum

Table 1: Disc type, read/record type, data layer, and metal layer

Basic Layers of CDs and DVDs

Basic layers of CD-ROM and DVD-ROM
(Replicated discs for audio, video, computer use, or interactive games)

CD-ROM (Single-sided)	DVD-ROM (Single-sided)	DVD-ROM (Single-sided)	DVD-ROM (Double-sided)	DVD-ROM (Double-sided)
(All CD-ROMs are one-sided) **One** recorded layer	(One side) **One** recorded layer	(One side) **Two** recorded layers	(Both sides) **One** recorded layer per side	(Both sides) **Two** recorded layers per side
Label, optional	Label, optional	Label, optional	Label, optional (hub area only)	Label, optional (hub area only)
Lacquer	Polycarbonate	Polycarbonate	Polycarbonate	Polycarbonate
Metal	Center adhesive	Metal (fully-reflective)	Metal	Metal (semi-reflective)
Polycarbonate	Metal	Center adhesive	Center adhesive	Adhesive
	Polycarbonate	Metal (semi-reflective)	Metal	Metal (fully-reflective)
		Polycarbonate	Polycarbonate	Center adhesive
			Label, optional (hub area only)	Metal (fully-reflective)
				Adhesive
				Metal (semi-reflective)
				Polycarbonate
				Label, optional (hub area only)

Basic layers of CD -R/-RW and DVD -R/-RW/+R/+RW/RAM
(Blank recordable discs for all applications listed for ROM discs)

CD-R, CD-RW (Single sided)	DVD-R, DVD-RW, DVD+R, DVD+RW, DVD-RAM (Single sided)	DVD-R, DVD-RW, DVD+R, DVD+RW, DVD-RAM (Double sided)
CD-R/RW are one-sided, **One** recordable layer only	(One side) **One** recordable layer only	(Both sides) **One** recordable layer per side only
Label, optional	Label, optional	Label, optional (hub area only)
Lacquer	Polycarbonate	Polycarbonate
Metal	Center adhesive	Recording/writing layer
Recording/writing layer	Metal	Metal
Polycarbonate	Recording/writing layer	Center adhesive
	Polycarbonate	Metal
		Recording/writing layer
		Polycarbonate
		Label, optional (hub area only)

The dye-based (R discs) and the phase-changing film layers (RW discs) both hold data by allowing or blocking light transfer through the data layer. The laser-affected ("written") areas of the data layer absorb the "reading" laser beam as it is emitted from the laser to the metal layer and reflected back to the laser photosensor. The light and dark areas give reflectivity effects that are similar to the interference effect of the "pressed" and molded data in the metal/substrate layer in ROM discs. The reflection, whether the result of dye, film, or pressed effects, is represented digitally as ones and zeros by the firmware in the disc drive as the laser reads the disc.

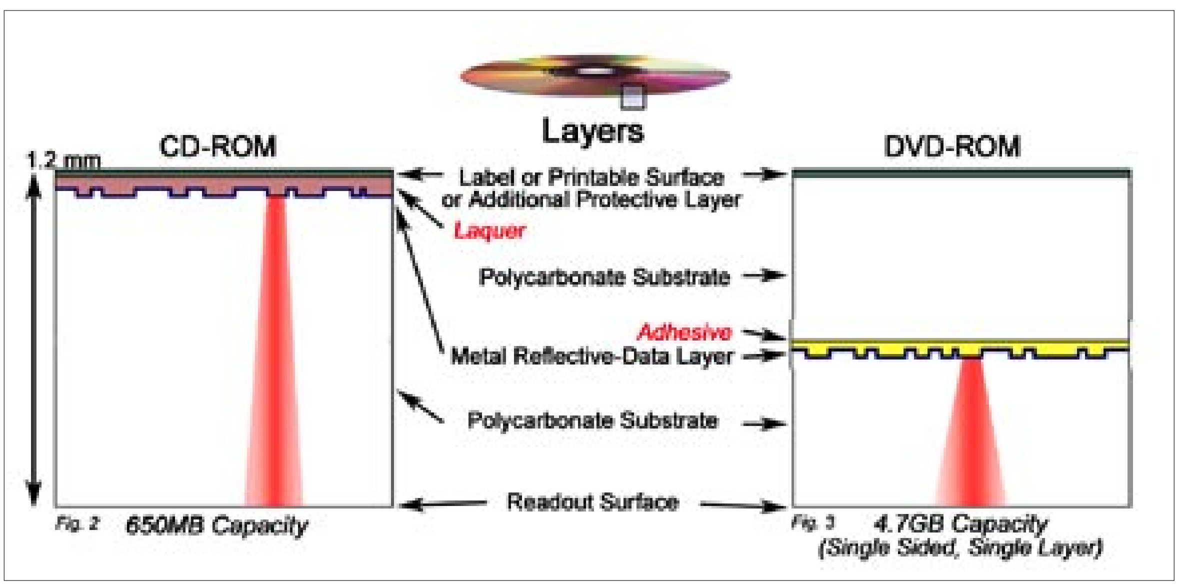
3.2.1 Data Layer in ROM Discs

ROM discs are commercially available or made-to-order prerecorded discs, also called "replicated" discs. Examples of CD-ROMs include the Audio-CD, Video-CD, CD-i, and CD+G, as well as any number of CDs used in computer applications. Among DVD-ROMs are the DVD-Video, DVD-Audio, and any of various DVDs used in games and computer applications.

The data in CD-ROM or DVD-ROM discs are not actually in a separate layer. A molding machine uses a stamper to impress the pits (depressions) and lands (surface), which form the data, into the polycarbonate substrate surface. Metal is then sputtered or condensed onto the molded substrate to form a "reflective data layer." The reflective metal layer in ROM discs can also be considered the data layer because the metal is integrated with the pits and lands in the polycarbonate (see Figures 2 and 3). The metal layer in ROM discs is usually aluminum. For double-sided DVD-ROM discs, the semi-reflective layer is gold, silver alloy, or silicon.

3.2.2 Data Layer in R Discs

The recordable, write-once optical disc (CD-R, DVD-R, DVD+R) has its data-recording layer sandwiched between the polycarbonate sub-



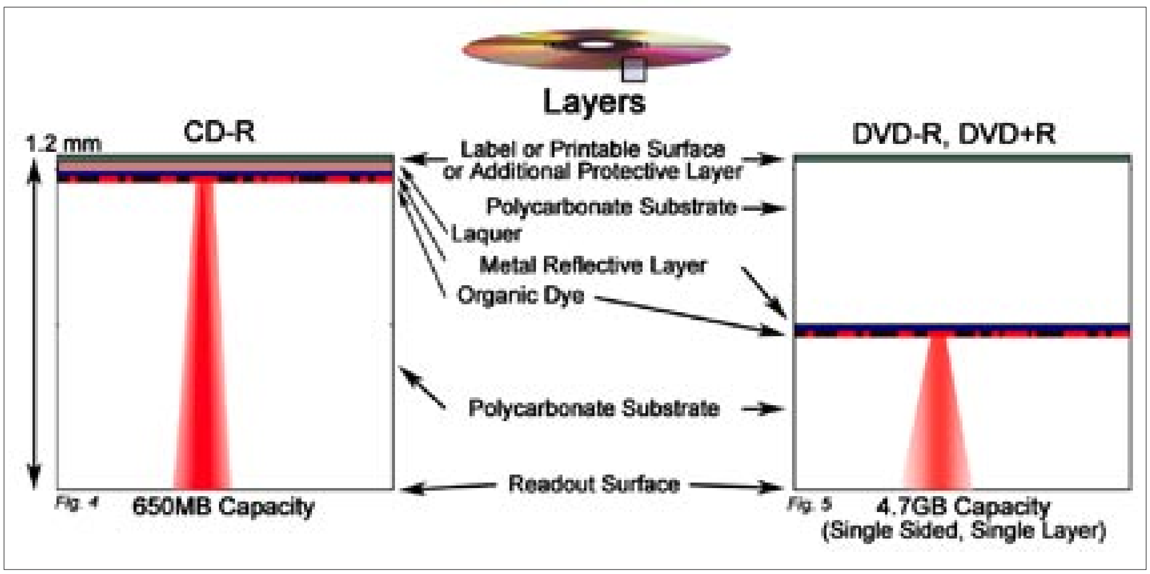
Figures 2, 3: Layers that make up ROM discs

strate and the metal layer (see Figures 4 and 5). This layer is an organic dye. The dyes used in CDs and DVDs are the same basic types; those used in DVDs, however, are patented by the manufacturer, and the disc color does not indicate the type of dye used. The dyes in both CDs and DVDs are photosensitive. Bits (marks) are written to the dye by a chemical change caused by the laser light beam. This dye degrades over time, eventually making the disc unreadable.

The data layer in CD-R discs consists of one of three basic dye types, each yielding a different disc color depending on the type of dye and the type of reflective metal used in the disc. Even on a plain, unlabelled disc, the label side can be a different color from the reading side. If the label side of a recordable disc does not have a printable surface, a label attached, or some other protective layer, it will have the color of the metal used (silver or gold). As for the laser reading side, the color will be as indicated in Table 2.

3.2.3 Data Layer in RW and RAM discs

The data-recording layer of the rewritable optical disc (CD-RW, DVD-RW, DVD+RW, DVD-RAM) also lies between the polycarbon-



Figures 4, 5: Layers that make up R discs

Dye Type		Color appearance (Viewing the laser reading side of the disc)	
	Actual Color	On Gold Metal	On Silver Metal
Phthalocyanine (thalo-sy-a-neen)	clear or very light green	gold or greenish gold	silver
Cyanine (sy-a-neen)	blue	green	blue
Azo (ay-zo)	dark blue or deep blue	dark green	dark blue or deep blue

Table 2: Dye type and color appearance—CD-R discs (recordable discs)

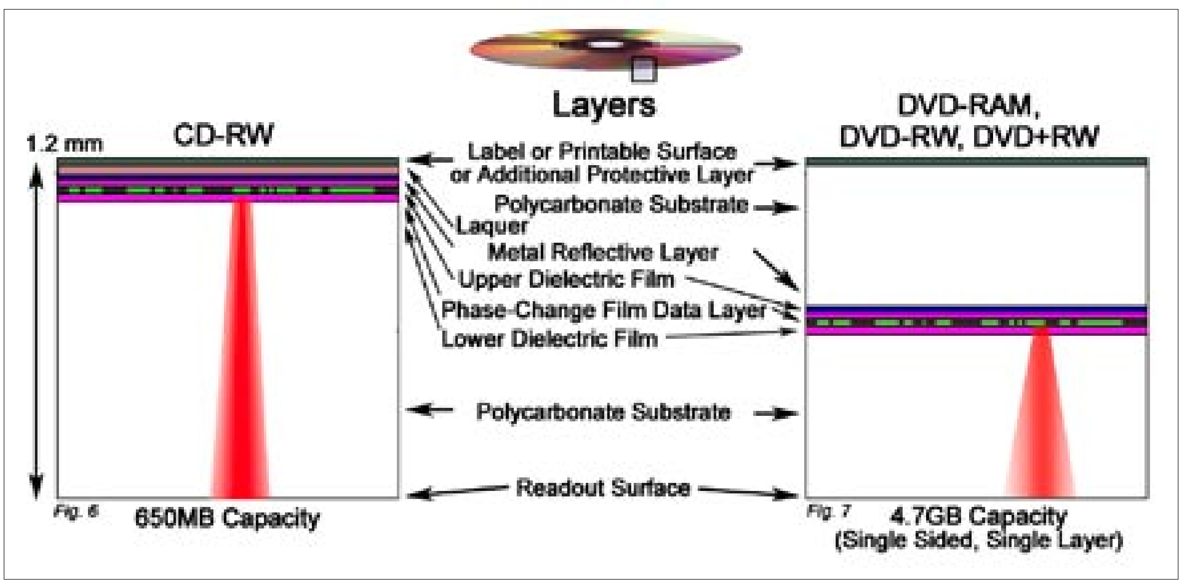
ate substrate and the metal reflective layer (see Figures 6 and 7). This is a phase-changing metal alloy film. A laser beam writes bits (marks) to the film by heating the film above the melting temperature in the areas selected for bits. The rapid cooling enabled by the dielectric layers on both sides of the phase-changing film causes these bit or mark areas to remain in the amorphous state caused by melting. By heating the phase-changing film to a specific temperature above the crystalline temperature but below the melting temperature, the film can revert back to the crystalline state, thereby erasing previous bits. The writing and erasing processes can be done together in a single pass when rewriting a disc.

3.3 Metal (Reflective) Layer

The metal layer in optical discs reflects the laser beam back to the laser photosensor in the laser head. Three types of reflective metals are typically used for this layer: aluminum, gold, and silver or silver alloy. In "double-layer" DVDs, silicon is sometimes used as one of the semireflective layers.

3.3.1 Metal Layer in RW, ROM, and RAM Discs

RW, ROM, and RAM discs (CD-RW, CD-ROM, DVD-RW, DVD+RW, DVD-ROM, DVD-RAM) use aluminum for the reflective layer, mainly because it is inexpensive and easy to apply. Aluminum oxidizes on exposure to oxygen from the environment or to moisture that has penetrated the disc. In some earlier CDs, poor sealing allowed oxygen to come into contact with the aluminum metal layer, causing the aluminum to oxidize. Oxidation of the aluminum diminishes its reflectivity, making the disc unreadable by the laser, and is sometimes referred to as disc "rot." It is the primary cause of ROM disc degradation from environmental influences. Not so, however, for



Figures 6, 7: Layers that make up RW and RAM discs

RW and RAM disc degradation; the phase-changing film in these discs normally degrades at a faster rate than the aluminum in the disc oxidizes.

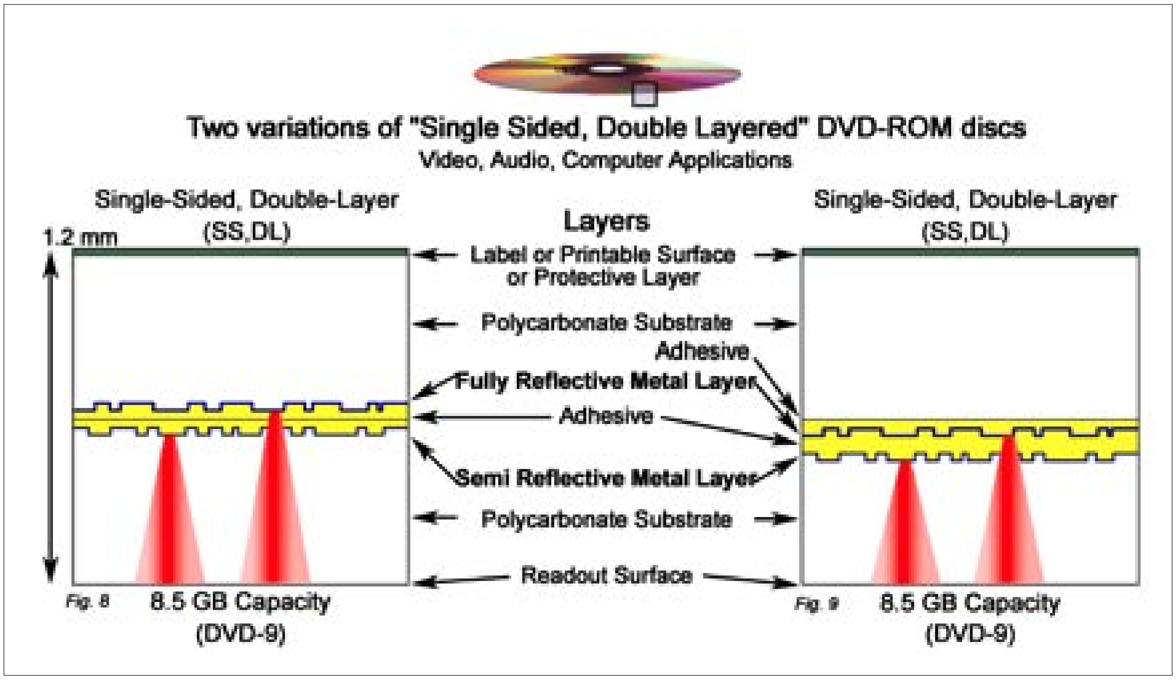
3.3.2 Metal Layer in R Discs

In R discs (CD-R, DVD-R, DVD+R), gold, silver, or a silver alloy is used for the reflective layer. Silver is slightly more reflective than gold but can lose reflectivity with corrosion on exposure to adverse environmental conditions. Silver corrodes through reaction with sulfur dioxide, an environmental pollutant that can migrate through the disc with moisture. Gold is noncorrosive, very stable, and longer lasting, but it is also expensive. Either metal should outlast the dye. Aluminum is not used with these discs because it can react with the dye in the recording (data) layer.

3.3.3 Metal Layers in Double-Layer DVD-ROM Discs

DVD-ROMs can be manufactured with two reflective metal layers that allow the laser to read data from both layers using one side of the disc. These "double layered" DVDs provide up to four times the capacity for content (video, audio, computer applications) as do "single-layered" DVDs. The laser beam must pass through a semi-reflective metal layer to read data from a fully reflective layer. The outer metal layer (silicon, gold, or silver alloy) is semi-reflective; that is, it reflects back some of the laser beam and allows some of it to pass through to a fully reflective layer (aluminum) and then reflect back. Both parts are thus reflected to, and detected by, the photosensor in the laser head, which focuses on one layer at a time.

Figure 8 shows the most common construction for single-sided, double-layered DVDs, while Figure 9 shows an alternative construction.



Figures 8, 9: Two types of double-layer, single-sided DVD-ROM construction

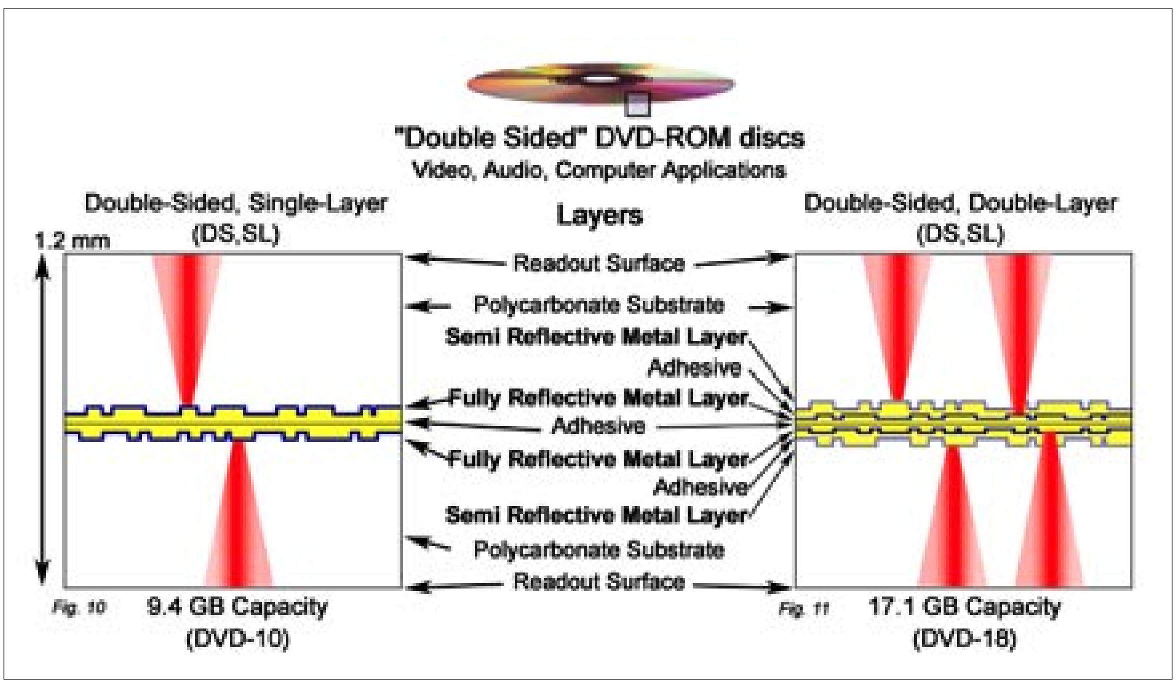
The difference between these two types is that one (Figure 8) has the metal data layers on separate sides (halves) of the disc. In addition to passing through a semireflective metal layer, the laser beam must also pass through a special adhesive that binds the two disc halves together and does not hinder the laser beam. In the example shown as Figure 9, the two metal data layers are on the same half of the disc.

DVD-ROMs can also be double-sided. Figure 10 shows a double-sided DVD that may typically be a DVD-Video providing the video in a full-screen TV version on one side of the disc and a wide-screen version on the other side. When double-sided DVDs also have double layers on both sides, they may have almost quadruple the capacity of single-sided/single-layered DVDs (Figure 11).

3.4 Lacquer (Metal Protective) Layer (CDs)

A very thin lacquer layer is applied to the label side of CDs to protect the metal from exposure to the environment. (DVDs have no such protective lacquer coating.) That layer also gives some limited protection from writing on or labeling the disc. However, the CD is more sensitive to damage on this side than on the polycarbonate side. Since the metal layer is so close to the surface of the label side, pointed objects can easily damage the CD by deforming the metal or exposing it to the environment. Some solvents can also affect lacquer coatings and expose or react with the metal. Once the metal is damaged, the laser cannot read data in the damaged areas.

Sometimes a manufacturer will add an additional layer designed specifically to provide more resistance to fingerprints and scratches on the label side of CDs. One particularly effective modification has



Figures 10, 11: Two types of double-sided DVD-ROM construction

been the application of lacquer completely around the edges of the disc. In earlier CDs, moisture had been allowed to penetrate to the metal through unprotected areas of the disc edge. Clearly, it is as important to protect the edges of CDs as it is their surfaces.

3.5 Optional Surface Layer

An optional layer may also be added to a CD or DVD to provide a labeling surface (see "Disk Surface Printing," page 24). Such surfaces are of four types:

- thermal-printable
- inkjet-printable
- silkscreen-printable
- a surface that will accommodate more than one type of printing

These layers are applied over the lacquer layer on CDs or over the polycarbonate substrate on a single-sided DVD. Some discs have an extra coating on which text or logos are printed. In many cases, the lettering appears to be stenciled, but it is not part of the coating; what one sees is the reflected surface of the metal rather than imprinted text or logos. Typically, one can see through this lettered area—and even through the metal—by holding the disc up to light.

Because these lettered areas are particularly susceptible to damage, it is most important to avoid writing on or scratching in these areas. The only disc surface area that is completely safe from writing or scratching is the clear inner hub or the "mirror band," since no data are recorded in these areas.

4. How Long Can You Store CDs and DVDs and Use Them Again?

The life expectancy (LE) of optical discs depends on many factors, some controllable by the user, others not.

Factors that affect disc life expectancy include the following:

- type
- manufacturing quality
- condition of the disc before recording
- quality of the disc recording
- handling and maintenance
- environmental conditions

As noted previously, the three basic types of CD and DVD discs—ROM, R, and RW and RAM—each use a different data layer material (molded aluminum, organic dye, or phase-changing film, respectively). Deterioration of this material is the primary cause for disc degradation and, ultimately, “end of life” for the disc, assuming proper physical handling.

Environmental factors can affect the rate of disc degradation. In each of the three basic disc types, environmental forces will degrade the data layer much faster than the polycarbonate substrate layer (the clear plastic that makes up most of the disc). Because degradation of the data layer will render the disc useless well before the polycarbonate begins to deteriorate, the relative degradation rate for the polycarbonate layer is not used for life expectancy considerations. Physical mishandling of the disc is usually the cause of polycarbonate layer damage. The polycarbonate may also flex or bend if stored for a long period of time in a nonvertical position.

So what is the life expectancy of a disc? First, we must define life expectancy. For most users, it means the length of time for which the disc remains usable. But that implies some acceptable amount of degradation. How much and what type of degradation is acceptable?

With CDs and DVDs, the user does not notice early degradation because the error detection and correction capability built into the system corrects a certain number of errors. The user notices a problem only when the error correction coding is unable to fully correct the errors.

One method for determining end of life for a disc is based on the number of errors on a disc before the error correction occurs. The chance of disc failure increases with the number of errors, but it is impossible to define the number of errors in a disc that will absolutely cause a performance problem (minor or catastrophic) because it depends on the number of errors left, after error correction, and their distribution within the data. When the number of errors (before error correction) on a disc increases to a certain level, the chance of disc failure, even if small, can be deemed unacceptable and thus signal the disc's end of life.

Manufacturers tend to use this premise to estimate media longevity. They test discs by using accelerated aging methodologies with controlled extreme temperature and humidity influences over a relatively short period of time. However, it is not always clear how a manufacturer interprets its measurements for determining a disc's end of life. Among the manufacturers that have done testing, there is consensus that, under recommended storage conditions, CD-R, DVD-R, and DVD+R discs should have a life expectancy of 100 to 200 years or more; CD-RW, DVD-RW, DVD+RW, and DVD-RAM discs should have a life expectancy of 25 years or more. Little information is available for CD-ROM and DVD-ROM discs (including audio and video), resulting in an increased level of uncertainty for their life expectancy. Expectations vary from 20 to 100 years for these discs.

Few, if any, life expectancy reports for these discs have been published by independent laboratories. An accelerated aging study at NIST estimated the life expectancy of one type of DVD-R for authoring disc to be 30 years if stored at 25°C (77°F) and 50% relative humidity. This testing for R discs is in the preliminary stages, and much more needs to be done.

4.1 CD-ROM, DVD-ROM Discs (audio, video, interactive games, +graphics, computer applications)

CD-ROMs and DVD-ROMs are similar in that they are replicated discs—that is, the data are physically pressed into the disc when it is manufactured. ROMs are generally mass-produced and contain music, video, computer applications, or interactive games.

ROM disc longevity is determined by the extent to which its aluminum layer is exposed to oxygen. Oxygen, including pollutants, can migrate through the polycarbonate layer or the hard lacquer layer (CD label side and edge), carried in by moisture. Oxygen or moisture can more easily penetrate through scratches, cracks, or delaminated areas in the label. Oxygen can also be trapped inside the disc during manufacturing, although manufacturing improvements have reduced the likelihood of this.

If left in a very humid environment, moisture—and oxygen—will eventually reach the aluminum, causing it to lose its reflectivity. The normally shiny aluminum, which resembles silver, becomes oxide-dull and much less reflective, like the color of a typical aluminum ladder. The combination of high humidity and increased temperatures will accelerate the oxidation rate.

The life expectancy of a ROM disc therefore depends on the environmental conditions to which it is exposed over time. Generally, it is best to keep ROM discs in a dry, cool environment. If the disc is removed from a humid, hot environment to an ideal condition before damage has been done, it will "dry out" and should be as playable as if it had been kept in ideal conditions all along. Other contaminates, however, such as inks, solvents, and pollutants, have the potential to irreversibly penetrate and to deform, discolor, or corrode the disc, causing permanent reading problems for the laser.

4.2 CD-R, DVD-R, DVD+R Discs

Most tests of optical disc life expectancy are performed with recordable discs (CD-R, DVD-R, DVD+R). The tests are generally performed by manufacturers, and the discs are usually categorized by the metal and dye types used in the disc. These discs use gold, silver, or a silver alloy for the reflective layer instead of aluminum as in ROM discs. Gold will not corrode but is expensive. Silver is more reflective and cheaper than gold but is susceptible to corrosion if exposed to sulfur dioxide, an air pollutant that can penetrate the disc in the same way oxygen can—with moisture. Manufacturers use various silver alloys to help inhibit silver corrosion, and most R discs available today use a silver alloy reflective layer. The chance of silver corrosion from exposure to sulfur dioxide is less than the chance of aluminum oxidation caused by high humidity. Nonetheless, keeping the disc in a filtered "clean air" environment can minimize or eliminate its exposure to sulfur dioxide. With proper storage, these discs will outlast the technology.

R discs use a dye-based layer (organic dye) for recording data. These are "write-once" discs and cannot be erased by CD or DVD drives. The organic dye used in the data layer of R discs degrades naturally but slowly over time. High temperatures and humidity will accelerate the process. Prolonged exposure to UV light can degrade the dye properties and eventually make the data unreadable. Heat buildup within the disc, caused by sunlight or close proximity to heated light sources, will also accelerate dye degradation.

Manufacturers claim that CD-R and DVD-R discs have a shelf life of 5 to 10 years *before* recording, but no expiration dates are indicated on CD-R, DVD-R, or DVD+R packaging, nor are there published reports of tests to verify these claims. Still, it would be prudent, in light of these claims, to purchase new discs as they are needed rather than to order large quantities and stockpile them for future use.

4.3 CD-RW, DVD-RW, DVD+RW, DVD-RAM Discs

RW and RAM discs are generally not considered for long-term or archival use, and life expectancy tests are seldom done for this medium. Rewritable discs use a phase-changing metal alloy film for recording data and aluminum for the reflective layer. The alloy film is not as stable as the dye used in R discs because the material normally degrades at a faster rate; however, these discs should still be stable enough to outlast the current CD or DVD technology.

The phase-changing film is affected primarily by heat, but ultraviolet (UV) light may also be a factor in the aging process. The combination of high temperature and UV light may further accelerate the aging process. The combination of high temperatures and high relative humidity will also most likely accelerate the aging process, just as it does with the organic dye used in R discs. No lab test results are yet available on the effects of these environmental conditions on RW or RAM discs.

The data on the phase-changing metal alloy film layer can be erased and rewritten to a limited number of times (about 1,000 times for RW discs and about 100,000 times for RAM discs). This rewriting does, however, affect disc life expectancy; RW or RAM discs archived after the first recording should have a longer life expectancy than those that have undergone several erase-recording cycles. Given the normal degradation rate alone, the life expectancy for RW and RAM discs will be less than that of R discs. Add to that multiple rewrites, and the life expectancy can be even less.

Just as the life expectancy of the disc varies with rewriting, so, too, does the security of the information itself. Information on RW and RAM discs is susceptible to loss or alteration as a result of the rewriting. Information on R discs is more secure precisely because it cannot be changed or rewritten.

5. Conditions That Affect CDs and DVDs

CDs and DVDs can be reliable for many decades with proper handling. As with all other types of media, degradation is inevitable over time, but steps can be taken to help prevent it from occurring prematurely. This section covers the effects of environmental conditions and physical handling on optical discs.

5.1 Environmental Conditions

5.1.1 Temperature and Relative Humidity

Optical discs will perform well within a wide range of temperature and relative humidity conditions. Discs kept in a cooler, less-humid environment and not subjected to extreme environmental changes should last longer. Optical discs stored in an optimal environment will outlast discs that are not. Storage temperature and relative humidity ranges recommended in various technical sources are presented in Table 3.

If stored at a very low temperature relative to the user environment, the disc should be gradually acclimated to the environment in which it will be used to reduce stress and moisture condensation. A

Source	Media	Temper-ature	Maximum Temp. Gradient	Relative Humidity (RH)	Maximum RH Gradient
ISO TC 171/SC Jan. 2002	CD-R CD-ROM	+5°C to 20°C (41°F to 68°F)	4°C /hr (7°F /hr)	30% to 50%	10% /hr
IT9.25 and ISO 18925 February, 2002	CDs DVDs	-10°C to 23°C (14°F to 73°F)		20% to 50%	Cycling no greater than: ±10%
NARA, FAQ About Optical Media, April, 2001	CDs DVDs	68°F (20°C)	+/- 1°F /day (+/- 0.6°C /day)	40%	5% /day
National Archives of Australia, April, 1999	CDs	18°C to 20°C (64°F to 68°F)		45% to 50%	10% /24 hrs
Library Technical Report Nov.-Dec. 1997	CDs	-10°C to 50°C (16°F to 122°F)		10% to 90%	
DVD Demystified, Second Edition, Jim Taylor, 2001	DVD-R DVD-ROM	-20°C to 50°C (-4°F to 122°F)	15°C /hr (27°F /hr)	5% to 90%	10% /hr
	DVD-RAM	-10°C to 50°C (16°F to 122°F)	10°C /hr (18°F /hr)	3% to 85%	10% /hr
	DVD+RW	-10°C to 55°C (14°F to 131°F)	15°C /hr (27°F /hr)	3% to 90%	10% /hr
National Library of Canada, 1996	CDs	15°C to 20°C (59°F to 68°F)	2°C /24 hrs (9°F /24 hrs)	25% to 45%	5% /24 hrs
Media Sciences, Inc. Jerome L. Hartke July 2001	CD-R	10°C to 15°C (50°F to 59°F)		20% to 50%	

Table 3: Recommended storage parameters from different sources

significant, abrupt temperature change will cause greater stress than a gradual change. Leaving the disc in its packaging will allow gradual acclimation to a changed environment. Discs used frequently should be stored at a temperature similar to that of the environment in which they are to be used. This minimizes stress from frequent temperature changes.

Given the absence to date of relevant testing, the precise effects of storing CDs and DVDs in freezing temperatures are not yet known. Freezing and thawing may create harmful stresses in the disc because of differing expansion rates of the layers, but it is unclear how much this stress might affect the disc. There may even be a benefit to uninterrupted freezing of a disc for an extended period. Until testing is done to measure the effects of freeze-thaw cycles or long-term freezing, the benefits or harmful effects will remain uncertain.

5.1.2 Light Exposure

Effect of Light on ROM Discs

Although the effect of light on ROM discs over time is not known, the effects of long-term exposure to light (e.g., UV, infrared, fluorescent) under ambient intensity, such as room lighting, are generally thought to be so minimal that light is not considered a factor in the lifetime of the ROM disc. Any effect of light on the disc would involve degradation of the polycarbonate substrate (plastic) and would become noticeable only after several decades of exposure to daily storage facility lighting or sunlight through windows. Degradation effects would likely be in the form of "clouding" or "coloring" of the polycarbonate. To our knowledge, there is no report on the potential impact of this kind of material change on the playability of the disc. Light effects on ROM discs, therefore, are considered negligible.

Effect of Light on R Discs

Prolonged exposure to sunlight or other sources of UV light can significantly increase the degradation rate of the dye (recordable) layer in R discs. Deterioration of the dye makes it less transparent. As a result, some, or all, of the unmarked areas in the dye could be read as marks, depending on the severity of degradation. These areas will then result in errors when read by the laser.

The most likely cause of damage to R discs from direct sunlight is by heat buildup in the disc affecting the dye. Much of the ultraviolet range of sunlight can be filtered (or absorbed) by glass—e.g., the glass of a window. However, the lower light frequency (infrared) range will pass through a window and generate heat in the disc. A disc in a case, or one with a dark label, printing, or color that allows it to absorb more sunlight, also makes a disc more prone to heat buildup from direct sunlight exposure. The effects of heat buildup can be minimized if the disc is kept cool, such as in an air-conditioned room. Exposure to direct sunlight without protection (glass or plastic window) will cause the disc dye to degrade more rapidly. These observations on the effects of light are based on preliminary tests conducted at NIST.

Direct sunlight to R discs is harmful for two reasons:

1. The sunlight's ultraviolet photons (the higher frequency of the sunlight spectrum) have enough energy to produce a photochemical reaction, altering the optical properties of the dye (recording layer) molecules.

2. The broad spectrum of unfiltered sunlight, infrared to ultraviolet (low frequency to high), can impart heat to the disc. The increased temperature generated by sunlight will accelerate the degradation or breakdown of the dye layer (recording layer) of the disc. The combination of high temperature and high relative humidity will further accelerate that degradation.

CD-R, CD-RW, DVD-R, DVD+R, DVD-RW. DVD+RW, and DVD-RAM discs can become unusable in a matter of days. If such a disc is left in an environment that allows direct sunlight and extreme heat buildup (e.g., on the dashboard of a car in summertime, or next to a heater by a window), the organic dye or phase-changing film that holds the data will degrade quickly, causing the disc to become unreadable. A disc is not protected from the effects of heat buildup if left in a case that is exposed to direct sunlight or other sources of heat. Extreme heat buildup can also cause warping of the disc.

Effect of Light on CD-RW and DVD-RW, DVD+RW, and DVD-RAM Discs

Light should have minimal, if any, effect on RW and RAM discs, for the phase-changing film used in such discs is not light sensitive. This film, however, is affected by heat; in fact, it is heat generated from the intense laser beam that writes data in the phase-changing film. Heat buildup in RW or RAM discs caused by direct sunlight will accelerate the degradation rate of the phase-changing film just as it does that of the dye in R discs. The phase-changing film in RW and RAM discs degrades naturally, and from heat buildup by direct sunlight, at a faster rate than the dye in R discs.

5.1.3 Moisture

The polycarbonate substrate, or the plastic composition, that makes up most of the disc is a polymer material that is vulnerable to moisture. Any prolonged exposure to moisture resulting from a spill, humid air, or immersion allows water to become absorbed into the disc, where it may react with any of the layers. Returning the disc to a dry environment will allow the absorbed moisture or water to dissipate out of the disc over time; however, water or a water-based liquid may leave behind, within the disc, contaminants such as dyes or other dissolved minerals. If the disc has experienced no permanent damage from absorption of the liquid, it should play normally. In NIST tests, a CD totally submerged in clean water for 24 hours was found to be unreadable initially after removal and surface drying. It played normally, however, after 24 hours of drying out at approximately 70°F and 50% relative humidity (normal room conditions).

5.1.4 Organic Solvents

Contact of the disc with strong organic solvents must be avoided. Harsher solvents such as acetone or benzene will dissolve the polycarbonate and thereby damage the disc beyond repair. Limited contact (cleaning) with mild solvents such as isopropyl alcohol or methanol is permitted, as these solvents evaporate quickly and will not dissolve the polycarbonate. They may, however, dissolve or damage labels or optional coatings on the label side of the disc.

5.1.5 Magnetism, X-rays, Microwaves, and Radiation

The effects on optical discs of magnetism, X-rays, microwaves, and radiation can be summarized as follows:

- Magnetism should have no affect on CDs or DVDs.
- X-ray exposure (e.g., from airport detectors) will not harm optical discs.
- Microwaves in a microwave oven will destroy a disc. (It may also destroy your microwave oven because of the metal in the disc.)
- Information on the effects of radiation is currently available from testing done in connection with the U.S. Postal Service's irradiation of mail to counter bioterrorism threats. CDs and DVDs have been tested at exposure levels of 60 to 300 kilogreys of radiation. According to the results, disc data were unaffected by the radia-

tion; the packaging and discs themselves, however, showed some discoloration and had a burnt-substance odor. There were no traces of residual radiation on any of the packages or discs (High-Tech Productions, no date). A quantitative summary of these effects is also available from Jerome L. Hartke, of Media Sciences, Inc.

5.1.6 Individual Disc Storage

Optical discs should be kept in individual storage containers until used and returned to those containers immediately thereafter. Typical storage containers, as listed below, isolate and help protect discs from airborne contaminants and other foreign material. They also help buffer rapid environmental changes that can cause stresses to the disc. Cases are designed to keep surfaces of the disc from contact with the inside of the case. Only one disc should be placed on the hub (or each hub) in the case. To remove the disc, one should press down on the hub tab while holding the outer edge of the disc with the fingers and then lift up. Bending the disc while lifting it off the hub tab should be avoided.

For long-term disc storage, it may sometimes be prudent to remove the label insert or booklet from inside the case and attach it to the outside, perhaps in a sleeve. In theory, the paper can attract moisture and produce higher moisture content in the case. The paper may also spread moisture by contact with the disc. This recommendation is based on no specific tests of the effects of paper inside a case; it is merely a consideration—one that takes on added significance with large amounts of paper inside a disc case and higher-than-recommended humidity conditions.

Cases commonly used for individual disc protection include the following:

- *Jewel case.* The jewel case, which comes in different varieties, holds one to six discs, depending on its design. It is typically a transparent plastic case with a hinged lid, one or more plastic trays, an inlay card for labeling, and an optional booklet.
- *Slimline case.* As its name suggests, a slimline case is a slimmer version of the jewel case but without the tray. It comes with an inlay card (J-card) and is primarily used for audio discs.
- *Amaray case.* An amaray case is a plastic case used for commercially available prerecorded (replicated) DVD videos and games.
- *Snapper case.* An alternative to the amaray case, the snapper case is a plastic DVD case with a cardboard cover that is snapped shut and held in place by a plastic lip.

5.2 Surface-Handling Effects

Anything on an optical disc surface that impedes the ability of the laser to focus on the data layer can result in missing data as the disc is being read. Fingerprints, smudges, scratches, dirt, dust, solvents, moisture, and any other foreign material can interfere with the ability of the laser to read the data. They can also interfere with the ability of the laser to follow the data track in the disc. Light scratches and fingerprints are very common, and while they both can impede laser reading, their effects on the disc are somewhat different. Scratches affect discs differently depending on the side of the disc affected, the severity and direction of the scratch, and the type of disc.

5.2.1 Scratches on the Laser-Reading Side of CDs and DVDs

Scratches generally cross data lines or tracks on the disc, and how bad (deep and wide) they are will determine the extent of interference with laser focus on the data. Small or occasional scratches will likely have little or no effect on the ability of the laser to read the disc, because the data are far enough below the surface of the disc that the laser is focused beyond the scratch. This is comparable to the effect of a light scratch on a pair of eyeglasses; it does not markedly impair vision because the viewer's eyes are focused beyond it.

Even assuming a scratch is deep or wide enough to influence laser focus, error detection and correction coding in the disc drive can in many cases recover the misread data. However, scratches that are deep, wide, or bunched together can adversely affect the readability of the disc. These scratches can cause the laser to misread enough data to make error correction coding ineffectual.

While data errors generated from scratches that run outward from the center of the disc stand a good chance of correction by the error correction firmware, scratches running in the direction of the track, the same direction as the laser reads the disc, are more likely to cause uncorrectable errors. These uncorrectable errors are called E32 in the Red Book for CD specifications, and PO Error in DVD specifications.

If scratches are deep enough to damage the data or metal layers on the reading side of a disc, the data cannot be read or repaired.

5.2.2 Scratches on the Label Side of CDs

Scratches on the label side of CDs can be a more serious problem. Because the reflective metal layer and data layer are so close to the surface of the label side of the disc, they can be damaged very easily. A slight indentation, or pinhole in the metal from a scratch, pen, pencil, ultrafine marker, or other sharp object will destroy the reflectivity of the metal in that area on the other side (laser reading side) and the readability of the data by the laser. This type of damage cannot be repaired.

As with scratches on the laser-reading side, optical disc drives are usually able to read through minor damage easily, even if the damage is caused from the label side. The difference is that this damage is permanent. If the error detection and correction firmware in the disc drive cannot correct the data, it will not be recoverable. Scratches that do not reach through the thin protective lacquer coating should have no immediate effect but may ultimately expose the metal to moisture, air pollutants, or other adverse environmental influences.

Adhesive labels (see page 23), though also somewhat vulnerable to adverse environmental influences, can provide CDs with extra protection from scratches. The extra layer on printable discs likewise offers protection.

5.2.3 Scratches on the Label Side of Single-Sided DVDs

Scratches on the label side of single-sided DVDs are not likely to pose a problem. The metal layer so prone to damage in CDs is in the middle of DVDs. Its location makes this layer almost impervious to surface scratches; it is in fact unlikely to be affected by any but the deepest scratches—those deep enough to reach the center of the disc where the metal and data lie.

5.2.4 Fingerprints, Smudges, Dirt, and Dust

Fingerprints, smudges, dirt, or dust on the laser reading side of the disc can disrupt laser focus on the data even more than a scratch can. Dirt or dust on the disc will block or reduce the light intensity of the laser. If severe enough, it will cause the disc drive to miss data as the disc is being read. Fingerprints, smudges, or dirt cover wide areas of data and will cause the laser beam to go out of focus or lose intensity. They will also cause widespread misreading of data along the data lines or tracks, to an extent that exceeds the error correction capability of the disc drive. Dust can also spin off into the disc drive and collect on the laser head or other internal components. Fingerprints, smudges, and dirt are easier to remove than scratches; it is simply a matter of cleaning them off.

To summarize, the effects of scratches versus fingerprints and smudges on the laser reading side of a disc include the following:

- Occasional fine scratches will typically not affect the focus of the laser.
- Deep scratches can affect the focus of the laser and cause errors.
- The error detection and correction coding system in the disc drive will correct many errors caused by scratches.
- Fingerprints and smudges can cause more errors than scratches and are more likely to overwhelm the error correction coding system capability.
- Scratches in the direction of the track (tangential direction) are worse than those going from the center of the disc outward (radial direction).
- Like fingerprints and smudges, several scratches close together can also overwhelm the error correction coding system capability.

5.2.5 Marking

Marking and labeling a CD or DVD is an essential process in its creation. CDs and DVDs, or their containers, are labeled in some form or fashion so that they can be identified and organized. When labeling a CD with markers, the composition of the ink in the marker and the style or design of the marker should be considered.

The inks in markers vary in chemical composition and are formed from pigments or dyes, and solvents. Inks are divided into three basic categories according to the type of solvent used: water-based, alcohol-based, and aromatic solvent-based. Within these categories, inks are further divided according to their permanence and their application to different surfaces.

Markers themselves also vary in form: there are fine-point, extra

> Never use a fine point or rolling ball marker on a CD because it may scratch or depress the surface of the disc and permanently damage the metal and data layers.

fine-point, rolling-ball, ballpoint, soft felt-tip, and chisel-tip. Some are ideal for CD labeling; others can cause damage.

Numerous CD vendors have noted that the thin protective lacquer coating can deteriorate from contact with certain solvents in markers. To eliminate the risk, water-based markers are recommended for CD labeling. As a solvent, alcohol is generally less damaging than xylene and toluene, which are common in aromatic solvent-based markers. According to anecdotal reports, alcohol-based markers can be used to label CDs without causing performance problems. However, there are no explicit lab test results to show what effect solvents in markers have on different CDs or DVDs, particularly over the long term.

The vulnerability of the metal in CDs, because of its proximity to the surface, should be considered when choosing a marker. The metal is particularly susceptible to damage from scratches, scrapes, or denting caused by surface marking. A felt tip marker will minimize the risk of scratching or denting.

As mentioned before, CDs and DVDs look similar, but their layer structures differ. The recording layer of a CD is located just beneath the labeling side. On a DVD, the recording layer is in the center of the disc. In theory, solvents from a solvent-based marker will not penetrate to the center of a DVD through the polycarbonate layer on both sides of the disc. Consequently, the data and metal layers in the center, in theory, should not come in contact with any harmful solvents. Nevertheless, the same precautions taken in labeling CDs are advisable for DVDs. The marker used to label a CD will work just as well on a DVD. Restricting oneself to the CD-safe marker will also eliminate the potential for mix-ups in the use of distinctive CD or DVD markers.

Many vendors sell CD-safe markers, and they vary in ink solution. They should not contain any solvents harmful to CDs or DVDs but should have a permanent quality. For risk-free labeling of any disc, it is best to mark the clear inner hub or the so-called mirror band of the disc, where there are no data (see Figure 12).

5.2.6 Flexing

Flexing (bending) the disc by any means, such as removing it from a jewel case or sitting on it, may harm the disc by causing stresses. The disc should be stored in its case and placed vertically, like a book, on a shelf. Long-term horizontal storage, particularly in a heated environment, can cause the disc to become permanently bowed. While the data may still be intact, the disc may not operate properly in the drive or permit the laser to follow the track. The maximum degree of flex (bend) or number of times a disc can be flexed before it incurs damage is not known. To minimize the risk of damage, it is better to avoid flexing discs.

5.2.7 Application of Adhesive Labels

Adhesive labels should not be applied to optical discs destined for long-term storage (more than five years). The label could delaminate over time and interfere with disc drive operation. The adhesive in some earlier labels has also been known to react with the lacquer surface. Any attempts to peel the label off could cause damage to the lacquer and metal layers in CDs. DVDs are different; peeling a label off a DVD would not have the same adverse affect because the metal layer is not near the surface. Still, removing a label, or any portion thereof, from the surface of a disc can cause an imbalance in the spin of the disc in the disc drive, making the disc unreadable. DVDs are more susceptible to reading problems from minor imbalances than are CDs. To ensure the long-term availability of information on a disc that already has an adhesive label, the information on the disc should be copied to, and stored on, a disc without such a label.

Adhesive labels may be well suited for short-term disc usage (less than five years), and can even add a layer of protection from scratches and other potentially harmful contact. On the other hand, such labels are vulnerable to adverse environmental conditions: they can dry out or absorb moisture, and they can be affected by heat or cold even more than the disc itself. Such conditions may cause the label to delaminate. Disc manufacturers advise against using adhesive labels because they can create unbalanced disc spin, resulting in premature wear of the drive. If a label is used, it should be manufactured for use on CDs or DVDs, and an appropriate disc label applicator tool should be used to affix the label. The label applicator tool should center the label on the disc so as to maintain the disc balance as much as possible.

Figure 12. Printable or markable areas of the disc

5.2.8 Disc Surface Printing

Printing labels directly on CD-R and DVD-R requires the use of discs to which a printable surface is added at time of manufacture. The following printing information relates mostly to CD-R discs, but would also apply to the DVD-R versions.

Inkjet printing and thermal transfer printing are commonly used for labeling the surfaces of CD-R discs. Each involves a different technology to place inks on the printing surface of the disc; few inkjet-printable and thermal printable CD-Rs are interchangeable.

The printable area on a DVD disc depends on whether the disc is single- or double-sided. A label may be printed on the top side of a single-sided DVD, much like on a CD. However, the performance of a DVD is more sensitive than that of a CD to any imbalance of the disk. Because ink affects the flatness and balance of a disc, full surface printing may not be the best choice since the ink may not be uniformly distributed over the disc surface. Nonetheless, if you choose to print labels on your discs, full surface printing is better than partial surface printing. For full surface printing of either a CD or a DVD, a white, printable base coat is available.

"Pit art" labeling, as an alternative to printing, avoids the flatness and balance issues. The pits are produced on the label side (without having a printable surface), creating a mirrored, holograph-like pattern on the metal layer that becomes the label. Because no ink is used, the flatness and balance of the disc are not compromised.

If a DVD disc has data on both sides (double-sided), neither printing nor pit art may be used in the data area of the disc. Only the area of the mirror band and the area between the mirror band and center hole may be printed on or marked.

Thermal Printing

In thermal transfer printers, a print head that contains resistive elements in a linear array heats ink-coated films (ribbons). The head is in direct contact with the uncoated side of the ribbon, and the ink-coated side of the ribbon is in direct contact with the disc's printable surface. The ink is heated, causing it to melt and adhere to the printing surface. Specially formulated materials are used for the printable surface of the disc to enhance ink transfer efficiency and adhesion. Only specially designed thermal printers—not thermal printers designed to print on paper—can be used to print directly on the surface of thermal printable CD-R discs.

Inkjet Printing

In inkjet printers, inks are sprayed, via droplets of an ink solution, onto a specially designed printable surface material on the disc. This surface is designed to hold the ink droplets in place while absorbing the liquid components of the ink.

Silkscreening

Silk screening on CDs or DVDs uses a UV-curable ink to keep the ink colors from running together. That ink cannot contain any chemically active components that can affect the disc after the curing process or abrasive particles in the ink pigments that can damage the protective layer of CDs.

5.3 Wear from Disc Play

CDs and DVDs do not wear from friction as vinyl records or tapes do. There is no physical contact with the disc in the area that the laser uses.

ROM Discs: The laser light will have no effect on the data or metal layer in ROM discs. In theory, it is possible for the disc to be read so many times that the cumulative effect of the laser light can eventually affect the polycarbonate. There is, however, no record of such discs having been played a sufficient number of times to incur damage from laser light. Accordingly, it is felt that any effects of the light on ROM discs is negligible. It is assumed, in fact, that the disc would likely fail much earlier from some other condition than from the effects of laser light.

R discs: In theory, R discs should have a limited number of read times (several thousand) because of the cumulative effect on the data layer from the laser light. As with ROM discs, the polycarbonate may also eventually be affected, but there is no recorded evidence of ill effects of laser light, so such effects are deemed negligible.

RW discs: RW discs, unlike the other types, can "wear-out." CD-RW and DVD-RW discs should last for about 1,000 rewrites, and DVD-RAM discs, 100,000 times, before the rewriting capability is lost. The reading functionality of the disc should continue for a limited number of read times after each writing. While the maximum number of read times possible after writing is unknown, it may become fewer after each successive writing.

6. Cleaning

CDs or DVDs do not require routine cleaning. It is best to clean the disc only when it is absolutely necessary, specifically:

- before storing, when surface contamination is visible
- before recording, when surface contamination is visible
- before playing, to prevent surface contamination from being "flung off" while the disc is spinning in the disc drive
- when readability (playability) is impaired and surface contamination is visible

In general, avoid using organic solvents. Harsher solvents (acetone, benzene) will dissolve the polycarbonate and damage the disc beyond repair. Mild solvents (isopropyl alcohol, methanol), however, may be used. These mild solvents evaporate quickly and will not dissolve the polycarbonate.

Other solutions that are not harmful are water-based lens cleaners or water-based detergents (with mild soap) formulated for cleaning CDs or DVDs.

The polycarbonate substrate is a relatively soft and transparent type of plastic. Each time a disc is wiped, rubbed, treated with some solution, or otherwise manipulated for cleaning, that substrate, and thus the disc itself, is at risk of scratching or contamination.

If the disc needs cleaning, remember these tips:

- Use an air puffer to blow off dust.
- Use a soft cotton cloth or chamois to wipe the disc.
- Try cleaning with a dry cloth first, before using any cleaning solutions.
- Do not wipe in a direction going around the disc.
- Wipe from the center of the disc straight toward the outer edge.
- Avoid using paper products, including lens paper, to wipe the disc.
- Avoid using anything abrasive on the surface of the disc.
- If the disc has a heavy accumulation of dirt, try rinsing it with water first.
- Use commercially available water-based detergent formulated for cleaning the surface of optical discs.
- Use isopropyl alcohol or methanol, as an alternate to water-based detergents, to clean the disc surface.

APPENDIX 1: COMMERCIALLY AVAILABLE CD/DVD DISC TYPES

CD

CDs are single-sided (One recorded layer or recordable layer on one side of the disc)

Disc	Type	Storage Capacity	Typical Uses
CD-ROM, Audio-CD, Video-CD	Read only	650MB	**Commercially available:** computer programs, music
CD-R	Record once	650MB	User recording music, computer data, files, applications
CD-R	Record once	700MB	
CD-RW	Rewritable	650MB	User recording computer data, files, applications
CD-RW	Rewritable	700MB	

DVD

- DVD-ROM, DVD-Video (commercially available pre-recorded DVDs), can be single- or double-sided with one or two data layers on one or both sides of the disc (a maximum total of four data layers).
- DVD-R, DVD+R, DVD-RW, DVD+RW, are only available as single-sided, single-layer (SS/SL).
- DVD-RAM is available in double-sided, single-layer (DS/SL).

Disc	Type	Storage Capacity	Typical Uses
DVD-ROM, DVD-Video, DVD-Audio			**Commercially available:** Movies Interactive games Programs Applications
Single side has one data layer (SS/SL)	Read only	4.7GB	
Single side has two data layers (SS/DL)	Read only	8.54GB	
Both sides have one data layer (DS/SL)	Read only	9.4GB	
Both sides have two data layers (DS/DL)	Read only	17.08GB	
DVD-R (General)	Record once	4.7GB	**General use:** One time video recording and data archiving
DVD-R (Authoring)	Record once	3.95GB or 4.7GB	**Professional use:** Video recording and editing
DVD+R	Record once	4.7GB	**General use:** One time video recording and data archiving
DVD-RW	Rewritable	4.7GB	**General use:** Video recording and PC back-up
DVD+RW	Rewritable	4.7GB	**General use:** Video recording and editing, data storage, PC back-up
DVD-RAM			**Computer data:** Storage repository for updateable computer data, back-ups
Single-sided	Rewritable	2.6GB or 4.7GB	
Double-sided	Rewritable	5.2GB or 9.4GB	

APPENDIX 2: OPTICAL MEDIA DRIVE TYPES AND HOW THEY HANDLE DIFFERENT DISC TYPES

DVD drive types and what they can do with each disc type

Disc Type	DVD ROM Play only (computer)		DVD-R (General) Records General -R		DVD-R (Authoring) Records Authoring -R		DVD-RW Records -RW, General -R		DVD-RAM Records RAM		DVD+R/+RW Records +R, +RW	
	Read	Write	Read	Write	Read	Write	Read	Write	Read	Write	Read	Write
DVD-ROM	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
DVD-R (General)	U	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No
DVD-R (Authoring)	U	No	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	No
DVD-RW	U	No	Yes	No	Yes	No	Yes	Yes	U	No	U	No
DVD-RAM	R	No	No	No	No	No	No	No	Yes	Yes	No	No
DVD+R	U	No	U	No	U	No	U	No	U	No	Yes	Yes
DVD+RW	U	No	U	No	U	No	U	No	U	No	Yes	Yes
CD-ROM	Yes	No	Yes	No	No	No	Yes	No	U	No	Yes	No
CD-R	Yes	No	Yes	Yes	No	No	Yes	Yes	U	No	Yes	Yes
CD-RW	Yes	No	Yes	No	No	No	Yes	Yes	U	No	Yes	Yes
	U = Usually R = Rarely											
DVD-Video DVD-Audio	All DVD drives should play DVD-Video or DVD-Audio if the computer has DVD-Video or DVD-Audio player software installed. DVD-RAM drives are questionable.											

* Most computer DVD drives are backward compatible to CDs, meaning they can read or read/write CDs.
* Some drives are the combination of more than one drive type, providing compatibility with different DVD and CD disc types.

CD drive types and what they can do with each disc type

Disc Type	CD ROM Play only		CD-RW or CD-R/RW Records -RW, -R		CD-R Records -R	
	Read	Write	Read	Write	Read	Write
CD-ROM	Yes	No	Yes	No	Yes	No
CD-R	Yes	No	Yes	Yes	Yes	Yes
CD-RW	Yes	No	Yes	Yes	No	No
DVD-Video, Audio DVD-ROM DVD-R (General) DVD-R (Authoring) DVD-RW DVD-RAM DVD+R DVD+RW	**DVDs do not work in CD drives or CD players.**					

Home DVD video player compatibility with each disc type

Disc Type	DVD Video Player	Comment
DVD-Video DVD-Audio	Plays	- DVD-Video and DVD-Audio are a type of DVD-ROM commonly used in home DVD-Video or DVD-Audio players. - Use of the term DVD-ROM, typically refers to replicated (commercially available pre-recorded) DVD-ROMs for computer applications.
DVD-ROM DVD-RAM	N/A	
DVD-R (General)	Depends	If the disc is formatted correctly, it should play in newer home DVD video players.
DVD-R (Authoring)		
DVD-RW, DVD+R, DVD+RW		
CD-ROM (Video-CD)	Depends	If the CD-ROM, CD-R, or CD-RW are formatted as V-CD, (Video-CD), some DVD video players will play them (some DVD players compatible with MPEG 1).
CD-ROM (Audio-CD)	Plays	
CD-R (V-CD or audio formatted)	Usually	
CD-RW (V-CD or audio formatted)		

Glossary

analog (content and storage media):

- analog content: content that uses a mechanism in which data are represented by continuously variable physical quantities (e.g., frequency and amplitude of sound recorded on tape, image printed on film).
- analog storage media: stores analog content (e.g., paper, photographic paper or negative, film, microfilm, audio tape, VHS tape, vinyl records, stone, cave wall).

To be used in computers, analog content must first be converted into a binary code. Such content that has been converted is often referred to as *digitized*. Digitizing is the “sampling” of an analog signal or content at predetermined interval locations; the signals are then converted into binary (1,0) form (digital). The closer the intervals, the more closely the digital signal represents the analog signal.

amaray case:
A plastic case normally used for commercially available prerecorded DVD videos and games.

archivist:
A person in charge of archives administration, including preservation.

archive:
(noun) A place where materials are preserved.
(verb) To file, collect, or store materials or media in an archive, or archive collection, for preservation.

audio CD, also, CD-DA (CD-Digital Audio), CD-A (CD-Audio):
A format that holds about 60 minutes of audio data, in up to 99 tracks (songs), to produce high-quality stereo sound. The success of audio CD (or CD-Digital Audio) has been key for the growth and success of CD-ROM and other CD formats.

bit:
The 1 or 0 that represents the smallest piece of data. Bits are used mostly when dealing with bandwidth rates (bits/sec), graphics resolutions, and related topics.

byte:
A string of 8 bits, operated upon as a unit. Bytes are typically used as a measure of file size or storage capacity.

CD (Compact Disc):
An optical disc. CD is a term loosely used when describing a variety of compact disc formats, from the production (mass-produced) audio and data discs, to the write-once “recordable” versions (CD-R) or write-many "rewritable" versions (CD-RW) CDs. The standard CD can hold about 650MB of data.

CD+G (Compact Disc plus Graphics):
Primarily used for karaoke, this type of CD embeds graphical data with the audio data, allowing video pictures to be displayed periodically as music is played. A special player is needed to read and display the information.

CD-I (Compact Disc-Interactive):
A compact disc format designed to allow interactive multimedia applications (digital audio and video, video games, and software applications) to be run on a player attached to a television.

CD-R (Compact Disc-Recordable):
A version of CD on which data can be recorded but not erased. An organic dye-based material is used to hold data that are written to it by a laser.

CD-ROM (Compact Disc-Read Only Memory):
An extension of the compact disc digital audio format that allows computer data to be stored.

CD-ROM drive:
A peripheral device attached to a computer that allows it to read and play all CDs.

CD-RW (Compact Disc-ReWritable):
A version of CD on which data can be recorded and erased and rerecorded in the same physical location of the disc. A phase-changing metal alloy film is used to hold the data that are written to it by the laser.

content:
Audio, video, photographic images, graphics, interactive games, computer applications, documents, files, databases, etc.; understandable information made up of data stored in a digital format.

copy:
(noun) Content that has been read from a source medium and written to another medium or to a separate space on the same medium.
(verb) To read data from a source, leaving the source data unchanged at the source, and to write the same data elsewhere, though the new medium may be in a physical form that differs from that of the source.

data:
Pieces of information from which "understandable information" is derived. In this guide, *data* refers to the bits (1, 0) recorded in the disc, from which applications or understandable information are derived.

data area:
The space on a CD or DVD where the digital content is located.

data layer:
The layer on an optical disc that holds data as marks or pits. They affect the amount of laser light that is reflected back to the laser photosensor.

dielectric layer:
A layer on both sides of the phase-changing film data layer in rewritable CDs and DVDs (RW and RAM) that rapidly cools the phase-changing film, allowing heated marks to remain crystallized.

digital:
The binary coding scheme generally used in computer technology to represent data as binary bits (1s and 0s). Digital information is often contrasted to analog information. Analog information can be digitized by sampling.

double-layered DVD:
A DVD that has two metal data layers, allowing for twice the storage capacity over single-layered DVDs.

disc drive:
A computer peripheral device that reads, or reads and writes, specific discs.

DVD:
Once stood for Digital Video Disc or Digital Versatile Disc, now just DVD. The next generation of optical disc storage technology after the CD. A DVD is the same physical size and shape as a CD, but has a higher density and gives the option for data to be double-sided or double-layered in the disc.

DVD-Audio:
An audio-only storage format similar to CD-Audio. DVD-Audio differs, however, in offering 16, 20 and 24-bit samples at a variety of sampling rates from 44.1 to 192KHz, compared with 16 bits and 44.1KHz for CDs. The latest audio format more than doubles the fidelity of a standard CD. DVD-Audio discs can also contain music videos, graphics, and other information.

DVD-R (DVD-Recordable, sometimes referred to as DVD minus R):
A version of DVD on which data can be recorded, but not erased, by a disc drive. An organic, dye-based material is used to hold data that are written to it by a laser. DVD-R provides secure recording for volumes of information that cannot be accidentally or intentionally altered. DVD-R has a capacity of 4.7 GB. There are two versions of DVD-R:

1. DVD-R (A) (DVD-Recordable for Authoring):
A format for professional content developers and software producers. Primarily used to create master discs that will be mass-produced by software houses and multimedia/video postproduction facilities.

2. DVD-R (G) (DVD-Recordable for General use) and DVD+R (DVD plus Recordable):
A format for general recording of all types of content: audio, video, and data. Compatible with most DVD-Video players and DVD-ROM drives.

The differences between DVD-R and DVD+R are as follows:
—DVD+R uses a different technique from DVD-R in how the laser follows the disc track while writing data to the disc. A writer disc-drive is generally capable of writing to one type of disc but some may be capable of writing to both types. All DVD drives should read both DVD-R and DVD+R.
—DVD-R uses constant linear velocity (CLV) for the disc rotation; DVD+R can use CLV or constant angular velocity (CAV) for the disc rotation. CAV allows for easier random access of data on the disc.
—DVD+R can provide lossless linking of new data added from multiple recording sessions.

DVD-RAM (DVD-Random Access Memory):
A rewritable DVD. It is a cartridge-based, or, more recently, cartridge-less optical disc for data recording and playback. Data can be recorded and erased up to 100,000 times, making the DVD-RAM a virtual hard disk. DVD RAM uses a phase-change data layer to record data written to it by a laser. Current DVD-ROM drives and DVD-Video players cannot read DVD-RAM media.

DVD-ROM (Read Only Memory):
Typically, an optical disc used for storing data, interactive sequences, audio, and video. DVD-ROMs run in DVD-ROM, DVD-R, DVD-RW, or DVD-RAM drives, but not in DVD-Video players connected to televisions and home theaters. However, most DVD-ROM drives will play DVD-Video movies if the associated software is installed in the computer.

DVD-RW (sometimes referred to as DVD minus RW, DVD-ReWritable):
The DVD-RW is similar to DVD-RAM except that its technology features a sequential read-write access more like a phonograph than a hard disk. Its read-write capacity is 4.7 GB, and it can be re-written to about 1,000 times. For general recording of all types of content, for audio, for video recording and editing, and for random data recording. Compatible with most DVD-Video players and DVD-ROM drives.

DVD+RW (DVD plus RW), (DVD-ReWritable):
For general recording of all types of content, for audio, for video recording and editing, and for random data recording. Compatible with most DVD-Video players and DVD-ROM drives.

The differences between DVD-RW and DVD+RW are as follows:
—DVD+RW uses a different technique from DVD-RW in how the laser follows the disc track while writing data to the disc. A writer disc-drive is generally capable of writing to one type of disc but some may be capable of writing to both types. Most newer DVD drives should read both DVD-RW and DVD+RW.
—DVD-RW uses constant linear velocity (CLV) for the disc rotation; DVD+RW can use CLV or constant angular velocity (CAV) for the disc rotation. CAV allows for easier random access of data on the disc.
—DVD+RW can provide lossless linking of new data inserted or added from multiple recording sessions.

DVD Video:
Used for viewing movies and for other visual entertainment, DVD Video is a popular format for high-quality MPEG2 or MPEG4 video and digital surround sound. It enables multilanguage, multisubtitling, and other advanced user features. The total capacity is 17 GB if two layers are used on both sides of the disk.

emulation technology:
Software or hardware that gives a computer, device, or program the ability to mimic the function of another computer, device, or program.

format:
Pre-established layout for data.

hub:
The area around the central hole of an optical disc, also called the clamping area. The spindle of the drive clamps the disc by this hub, which should fit precisely to provide reliable centering and eliminate flutter as it transfers the rotational movement imparted by the motor. While CD products use this area for serial number and other replication plant production codes, double-sided DVDs will use it for identification information as well.

information:
Meaningful expression or interpretation of data.

jewel case:
A clear plastic hinged container used to package and store a compact disc or DVD. It typically includes a plastic tray to hold the disc, an inlay card for labeling, and, often, a booklet in the front of the case.

lacquer layer:
A very thin layer applied to CDs to protect the metal layer from exposure to the environment. It also provides limited protection from writing on or labeling of the disc.

laser photosensor:
A component of an optical disc drive that senses whether or not it is receiving laser light of a particular frequency with a detectable intensity.

layer:
A single thickness or stratum within a disc.

life expectancy (LE):
The number of years the disc is expected to be useful. The life of a disc is considered at its end when the error rate exceeds a predermined limit, as measured before the error correction process, even if the disc is still playable and the errors are not noticeable to the user.

mark:
A low reflectance feature of a recording layer representing data that can be sensed by an optical system.

media:
Plural of medium

medium:
Material on which data are or may be recorded, such as paper, punched cards, magnetic tapes, magnetic disks, or optical discs.

metal layer:
The layer in optical discs that reflects the laser beam back to the laser photosensor. Aluminum, gold, silver, or silver alloy are generally used depending on the type of disc.

mirror band:
Slender ring of highly reflective silver that extends from the outer edge of the clear inner hub at 38 mm to the inner edge of the main printable area of the disc at 46 mm.

optical disc:
A plastic disc that is "written" (encoded) and "read" using a laser optical device. The disc contains a highly reflective metal and uses bits to represent data by containing areas that reduce the effect of reflectance when illuminated with a narrow-beam source, such as a laser diode. The bits (data) are stored sequentially on a continuous spiral track starting from near the center of the disc and going to the outer edge.

original:
The first representation or generation of specific content or an object.

organic dye (dye polymer):
A photosensitive organic chemical located between the polycarbonate substrate and metal layers and comprising the data layer of a recordable CD or DVD. The dye darkens when exposed to intense light (laser) of a particular wavelength.

oxide-dull:
The less reflective state of a metal caused by oxidation.

oxidation:
A chemical reaction between oxygen and another substance, causing the original substance to have its properties altered. In the case of aluminum, oxidization reduces its reflectivity.

phase-changing film:
A metal alloy (silver, indium, antimony, and tellurium), sandwiched between two dielectric layers and located between the polycarbonate substrate and metal layers. It is the data layer of rewritable (RW and RAM) CDs and DVDs. Data is written to this layer after a laser beam heats the film, causing crystallization (a phase change) to occur. The crystallization remains intact because of rapid cooling caused by the dielectric layer on both sides of the film.

photochemical reaction:
The chemical reaction in CD-R and DVD-R discs resulting from the interaction of the organic dye and laser light. The interaction results in a change of property of the organic dye in the areas exposed to the laser light. These areas are known as bits or data that have been "written" into the organic dye.

playback system:
A set of devices that can play or display disc information.

polycarbonate substrate:
The transparent physical layer that makes up most of an optical disc. It also provides mechanical support through which a laser can access an information layer.

pre-recorded disc:
A replicated disc, also called ROM disc. Generally, commercially available discs with content recorded on them during manufacturing.

preservation:
(The definition is slightly adapted from the National Archives and Records Administration)

Preservation encompasses the activities that prolong the usable life of materials. Preservation activities are designed to minimize the physical and chemical deterioration of materials and to prevent the loss of informational content. These activities include providing a stable environment for materials of all media types, using safe handling and storage methods, duplicating unstable materials (e.g., nitrate film, thermofax) to stable media, copying potentially fragile materials into a usable format (e.g., microfilming or digitization), storing materials in housings made from stable materials (for example, document boxes made from "acid-free" paperboard), repairing documents to maintain their original format, establishing a pest control program, and instituting a disaster recovery plan that includes plans for emergency preparedness and response.

pressed discs:
Mass-produced, replicated discs (usually perecorded, commercially available discs). The data on these discs are molded as an integral part of the polycarbonate substrate during the manufacturing process by applying a metal layer (aluminum) to the side of the polycarbonate substrate containing the "land/bit" form. Also called *ROM* or *replicated disc*.

read:
An operation that results in the flow of data from an object (CD, DVD) to a subject (CD drive, DVD drive).

record:
To write data on a medium, such as magnetic tape, magnetic disk, or optical disc.

recordable:
Media that data can be written to. Among optical discs, examples are CD-R, DVD-R/+R, CD-RW, DVD-RW/+RW, and DVD-RAM.

Red Book for CD specifications:
Document developed by Sony and Philips in 1980 that provides the first specifications for standard compact discs (CD).

reflectance (reflectivity):
Proportion of incident light that is returned from a reflective surface.

removable storage:
Media or hardware used for storing data (content) that is easily removable from, and that can be stored separately from, its associated hardware. Examples are CDs and DVDs.

replicated disc:
Generally, a commercially available disc on which content was recorded during the manufacturing process. Also called ROM disc.

rewritable (RW):
Recordable storage medium that can be overwritten multiple times, normally without pre-erasure. Examples are CD-RW, DVD-RW, DVD+RW, and DVD-RAM.

RH:
Relative humidity

ROM:
Read only memory. Generally, a commercially available disc on which the content was recorded during the manufacturing process. Also called replicated disc.

single-sided:
A disc on which data can be read or written to (recordable discs) from one side only.

single-layered DVD:
A DVD that contains only one metal and data layer, on one or both sides.

slimline case:
A slimmer version of the jewel case. Unlike the jewel case it does not contain the plastic tray, but instead uses an inlay card (J-card). Primarily used for audio discs.

snapper case:
A plastic DVD case with cardbard cover that is snapped shut and held in place by a plastic lip. An alternative to the amaray case for storage of pre-recorded DVDs.

storage:
Retrievable retention of data. Electronic, electrostatic, electrical, hardware or other elements (media) into which data may be entered, and from which data may be retrieved, as desired. Also, a facility or place that houses hardware or media.

storing:
The action of holding something (CDs, DVDs) in storage.

UV light:
Light found between the end of the visible light spectrum (violet, 400 nm wavelength) and the beginning of the X-ray spectrum (100 nm wavelength). Common sources include solar rays and fluorescent black lights.

Video CD (V-CD):
A standard for displaying full motion pictures with associated audio on CD. The video and sound are compressed together using the MPEG 1 standard and recorded onto a CD Bridge disc.

WORM:
"Write-Once-Read-Many" recording on non-erasable blank media that contain pre-stamped grooves to guide a write laser.

write:
To record data onto a recordable or rewritable media from a disc drive.

write-once:
A recordable storage medium that cannot be erased or re-written. Optical disc examples are: CD-R, DVD-R, DVD+R. The R indicates recordable disc.

Bibliography

All URLs were valid as of September 15, 2003

Adelstein, Peter Z. 1999. Permanence of Digital Information. Access to Information Preservation Issues. Proceedings of XXXIV International Conference of the Round Table on Archives (CITRA 1999), Budapest: International Council on Archives.

Anglim, Chris. 1997. Preserving the CD-ROM. *Technical Services Law Librarian* 22(4). Available at http://www.aallnet.org/sis/tssis/tsll/22-04/presrv.htm.

BC Archival Preservation Service. 2001. Optical Disk Media. *AABC Newsletter* 11(3). Vancouver: Archives Association of British Columbia. Available at http://aabc.bc.ca/aabc/newsletter/11_3/bc_archival_preservation_service.htm.

Campbell, Daniel R. 2000. Digital Preservation Strategies, What's Good. What's Bad. What Should You Do? *AALL Spectrum* (December). American Association of Law Libraries.

CD-Info Company. 1997. Customizing CDs. Available at http://www.cd-info.com/CDIC/Technology/CD-R/Labeling/.

Clatterbuck, Tim. 1999. Choose CD-R, CD-RW Media as Though your Data Life Depends on it. *International Journal of Micrographics & Optical Technology* 17(4).

Clifton, P. 2001. Nonprint Media Update: Longevity and Optical Media. *DTIC Digest*, no. 1 (January). Defense Technical Information Center. Available at http://www.dtic.mil/dtic/digest/digest2001-1/Nonprintmed.html.

CNET Networks, Inc. 2001. Care and Feeding of CD-Rs. Available at http://computers.cnet.com/hardware/0-1091-8-8020643-6.html?tag=st.co.1091-8-8020643-1.txt.1091-8-8020643-6.

CNET Networks, Inc. 2001. Disc Anatomy 101. Available at http://computers.cnet.com/hardware/0-1091-8-8020643-5.html?tag=st.co.1091-8-8020643-1.txt.1091-8-8020643-5.

Cochrane, Katherine. 1998. Recordable CD and DVD for Archiving. *Microscopy Today* No. 98-10.

Conservation Online. 2003 (May 5). NARA/Long-Term Usability of Optical Media. Available at http://palimpsest.stanford.edu/bytopic/electronic-records/electronic-storage-media/critiss.html.

Ditzler, Carol, Caroline Early, and Claudia Weston. 1994. Preservation Issues for Optical/Electronic Media. Chapter 7 in The Electronic Information Initiative, Phase 1 Final Report (Revision 3). Available at http://www.nal.usda.gov/services_and_products/other_nal_products/eii/nal-eii7.html.

DVD Club Review. No date. DVD Care and Handling. Available at http://www.dvd-club-review.com/dvdguidecare.htm.

Eastman Kodak Company. 2002 (April 2). Handling Kodak CD-R Media. Available at http://www.kodak.com/cluster/global/en/service/tib/tib4356.shtml.

Eastman Kodak Company. 2002 (March 5). Labeling Kodak CD-R Media. Available at http://www.kodak.com/global/en/service/tib/tib4298.shtml.

Eastman Kodak Company. No date. Permanence and Handling of CDs. Available at http://www.kodak.com/global/en/professional/products/storage/pcd/techInfo/permanence1.jhtml?id=0.3.6.30.17.6&lc=en.

Frey, F., S. Susstrunk. 2000. Digital Photography—How Long Will It last? Paper presented at ISCAS 2000: IEEE International Symposium on Circuits and Systems, Geneva, Switzerland, May 28–31, 2000.

Gilbert, Michael W. 1998. Digital Media Life Expectancy and Care. *@OIT* (Fall). University of Massachusetts Office of Information Technologies. Available at http://www.oit.umass.edu/publications/at_oit/Archive/fall98/media.html.

Hartke, Jerome L. 2000 (May 22). CD-R Media Survey. Available at http://www.mscience.com/survey.html.

_____. 2001 (July 17). Measures of CD-R Longevity. Available at http://www.mscience.com/longev.html.

_____. 2002. Why CD-Rs Fail. *Medialine* (October). Available at http://www.mscience.com/cdrfail.html.

_____. 2002. Irradiation of CD Discs Sent by U.S. Mail. *Medialine* (July). Available at http://www.mscience.com/radiate.html.

High-Tech Productions. No date. Postal Service Selects Titan to Eradicate Bio-Threat in U.S. Mail. High-Tech Productions to conduct Media Testing with Titan. http://www.high-techproductions.com/radiationtesting.htm.

Hirota, Kusato, and Gentaro Ohbayashi. 1997. Reliability of the Phase Change Optical Disc. *Japanese Journal of Applied Physics* Part I 36(10): 6398–6402.

Imation, 2002. Handle with Care: Making Your CD-R & CD-RW Media Last. http://www.imation.com/assets/en_US_Assets/PDF/IMN_CDcare.pdf.

International Organization for Standardization. 2002. International Standard ISO 18921, Imaging materials—Compact discs (CD-ROM)—Method for estimating the life expectancy based on the effects of temperature and relative humidity. Geneva: International Organization for Standardization.

Kushnier, Ron. No date. Care and Handling of CD-ROM Discs. Available at http://www.scn.rain.com/pub/cdrom/handling.

Lee, Kyong-Ho, Oliver Slattery, Richang Lu, Xiao Tang, and Victor McCrary. 2002. The State of the Art and Practice in Digital Preservation. *Journal of Research of the National Institute of Standards and Technology* 107: 93–106. Available at http://nvl.nist.gov/pub/nistpubs/jres/107/1/j71lee.pdf.

Library of Congress. National Digital Information Infrastructure and Preservation Program. Available at http://www.digitalpreservation.gov/.

Marschall, Mary E., and Ginni Voedisch. 1990. Compact Discs: Permanence and Irretrievability May Be Synonymous In Libraries As Well As In Roget's. National Online Meeting Proceedings. Medford, N.J.: Learned Information.

Maxell Corporation of America. No date. Tech Info. Available at http://maxell-data.com/techinfo/whitepapers/.

Maxell Corporation of America. No date. Maxell DVD-R White Paper. Available at http://www.maxell-data.com/techinfo/whitepapers/dvd-r_white.shtml.

Media Sciences, Inc. No date. Frequently Asked Questions. Available at http://www.mscience.com/faq.html.

Mitsui Advanced Media, Inc. No date. Mitsui DVD-R. Available at http://www.mitsuicdr.com/technology/technical_papers/documents/DVD-R_information.pdf.

_____. No date. CD-R Dyes: How to Tell What's What. Available at http://www.mitsuicdr-store.com/Dyes.htm.

_____. No date. Silver vs. Gold: Which is Best for Me? Available at http://www.mitsuicdr-store.com/silver&gold.htm.

_____. 1999. Handling and Storage Guidelines. Available at http://www.mitsuicdr-store.com/handling_instructions.pdf.

National Archives of Australia. 1999 (April). Protecting and Handling Optical Discs. Available at http://www.naa.gov.au/recordkeeping/rkpubs/advices/advice6.html.

National Archives and Records Administration. 2001 (April). Frequently Asked Questions About Optical Media. Available at http://www.archives.gov/records_management/policy_and_guidance/frequently_asked_questions_optical.html.

National Institute of Standards and Technology, Information Technology Laboratory. 2003 (Jan. 16). Data Preservation Program. Available at http://www.itl.nist.gov/div895/isis/datastorage.html.

National Library of Australia. 2001 (December). Preserving Access to Digital Information (PADI), Optical Discs. Available at http://www.nla.gov.au/padi/topics/53.html.

Optical Storage Technology Association. 2001. Technology: Q&A. Understanding CD-R & CD-RW. Available at http://www.osta.org/technology/cdqa.htm.

PCTechGuide. 2003 (March 27). Storage: CD ROM. Available at http://www.pctechguide.com/08cd-rom.htm.

_____. 2003 (March 27). Storage: CD-Recordable/CD-Rewritable. Available at http://www.pctechguide.com/09cdr-rw.htm.

_____. 2003 (March 27). Storage: DVD. Available at http://www.pctechguide.com/10dvd.htm.

Pioneer Electronics Service, Inc. No date. CD Care and Information. Doc No. 14038. Available at http://legacy.pioneerelectronics.com/Pioneer/Files/14038.pdf.

Pohlmann, Ken. 1992. The Compact Disc Handbook, 2nd ed. Middleton, Wisc.: A-R Editions.

Saffady, William. 1997. Stability, Care, and Handling of Microfilms, Magnetic Media and Optical Disks. *Library Technology Reports* 33(6): 709.

St. Laurent, Gilles. 1996. The Care and Handling of Recorded Sound Materials. National Library of Canada. Available at http://palimpsest.stanford.edu/byauth/st-laurent/care.html.

SANYO Laser Products, Inc. 2002. DVD—Frequently Asked Questions. Available at http://www.sanyolaserproducts.com/dvd/faq.htm.

Sharpless, Graham. 2003. CD and DVD Disc Manufacturing. Deluxe Global Media Services, Ltd. Available at http://www.disctronics.co.uk/downloads/tech_docs/replication.pdf.

______. 2003. An Introduction to DVD Formats. Deluxe Global Media Services, Ltd. Available at http://www.disctronics.co.uk/downloads/tech_docs/dvdintroduction.pdf.

______. 2003. Introduction to CD and CD-ROM. Deluxe Global Media Services, Ltd. Available at http://www.disctronics.co.uk/downloads/tech_docs/cdintroduction.pdf.

Sony Electronics Inc. 2003. Care and Handling/CD-R and CD-RW. Available at http://www.mediabysony.com/NASApp/ctsc/customer_resources.jsp?documentid=6.

Stinson, Douglas, Fred Ameli, and Nick Zaino. 1995. Lifetime of KODAK Writable CD and Photo CD Media. Available at http://www.cd-info.com/CDIC/Technology/CD-R/Media/Kodak.html.

Taylor, Jim. 2003 (Sept. 22). DVD Demystified: DVD Frequently Asked Questions (and Answers). Available at http://www.dvddemystified.com/dvdfaq.html.

TDK. No date. TDK CD-R Technology. Available at http://www.cd-info.com/CDIC/Technology/CD-R/Media/TDK.html.

Technical Advisory Service for Images. 2002 (March). An Introduction to Digital Preservation. TASI Advice Paper. Available at http://www.tasi.ac.uk/advice/delivering/pdf/digpres.pdf.

_____. 2002 (September). Using CD-R and DVD-R for Digital Preservation. TASI Advice Paper. Available at http://www.tasi.ac.uk/advice/delivering/pdf/cdr-dvdr.pdf.

Titan Corporation San Diego, Organic Consumers Association, Effects of Electronic Beam Irradiation on Nonfood Substance, Initial Beam Effects Summary. Available at http://www.organicconsumers.org/irrad/ebeamnonfood.cfm.

Van Bogart, John W. C. 1995. Magnetic Tape Storage and Handling. Washington, DC: Commission on Preservation and Access and St. Paul, Minn.: National Media Laboratory. Available at http://www.clir.org/pubs/reports/pub54/index.html.

Verbatim Corporation. 2001. FAQ: What is the Proper Care and Handling for Optical Discs? Available at http://www.verbatim.com/products/products.cfm?showfaq=16&search=1.