

Understanding Recordable & Rewritable DVD

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Optical Storage Technology Association (OSTA)

Market Development Committee

Author's Notes

In the continuing evolution of writable optical storage beyond CD-R and CD-RW, recordable and rewritable DVD meet the expanded demands of personal and professional video as well as still uncharted applications.

This document is a compliment to my earlier "Understanding CD-R & CD-RW" white paper. Thus, explanations are provided to satisfy essential questions about DVD-R, DVD+R, DVD-RW, DVD+RW and DVD-RAM product technology and offer direction to sources of further information.

Suggestions to improve the accuracy, completeness or effectiveness of this paper are welcomed by the author who can be contacted by email: hugh_bennett@compuserve.com.

Sincerely,

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PHYSICAL, LOGICAL AND APPLICATION SPECIFICATIONS

What writable DVD formats are available?

There are five kinds of writable DVD technology (DVD-R, DVD+R, DVD-RW, DVD+RW and DVD-RAM). Similar to CD-Recordable (CD-R), DVD-R and DVD+R discs are write-once incorporating a dye recording layer to which information is irreversibly written by means of a laser heating and altering it to create a pattern of marks mimicking the pits of a prerecorded (pressed/molded) DVD. DVD-RW and DVD+RW, on the other hand, closely resemble CD-ReWritable (CD-RW) by employing a phase-change recording layer that can be repeatedly changed and restored by the writing laser (approximately 1000 times). DVD-RAM also uses phase-change technology but can be rewritten roughly 100,000 times. With its hard sectors, random access capabilities and optional cartridge, DVD-RAM more closely resembles traditional disc-based storage media than do DVD-RW and DVD+RW. This separates DVD-RAM somewhat from the prerecorded DVD format that provides the basis for most DVD discs.

Due to technological limitations when it was introduced in 1997, DVD-R employed 635 nm wavelength laser technology to store 3.95 GB per 12 cm disc (DVD-R version 1.0). Capacity was increased to 4.7 GB per disc in 1999 (DVD-R version 1.9). In 2000, DVD-R was split (DVD-R for Authoring version 2.0 and DVD-R for General version 2.0). DVD-R (Authoring) continues to use a 635 nm laser and remains available in limited form as do 3.95 GB discs for some highly specialized applications while the less expensive DVD-R (General) is more widely used and employs the same 650 nm laser wavelength as other DVD formats.

In 1999 DVD-RW was introduced only in Japan (version 1.0) with 4.7 GB 12 cm discs incorporating an embossed information area (for content protection) unreadable by nearly all DVD devices. This was changed in 2000 (version 1.1) to make discs broadly compatible.

DVD-RAM first appeared in 1998 offering 2.6 GB of storage per 12 cm disc (version 1.0) growing to 4.7 GB in 1999 (version 2.0). A 1.46 GB 8 cm disc was introduced in 2000 (version 2.1).

Originally, a 3.0 GB version of DVD+RW was proposed but no products were ever released. DVD+RW came to market in 2001 with a capacity of 4.7 GB per 12 cm disc while DVD+R arrived in 2002.

What specifications govern writable DVD discs?

As is the case with CD-R and CD-RW, all DVD disc formats are governed by a variety of industry specifications or “books” defining their mechanical properties, optical signal characteristics, physical arrangement, writing methods and testing conditions. In addition, various documents also deal with file systems as well as applications.

Specifications for DVD physical formats (DVD-ROM, DVD-R, DVD-RW, DVD-RAM) and applications (DVD-Video, DVD-Audio, DVD-ENAV, DVD-VR, DVD-AR, DVD-SR) were established and are continually updated (increases in writing speed, etc.) by the DVD Forum (originally DVD Consortium), an association of manufacturers founded in 1995 by Hitachi, Matsushita Electric, Mitsubishi Electric, Pioneer, Philips Electronics, Sony, Thomson, Time Warner, Toshiba and JVC.

DVD+R, DVD+RW and DVD+MRW (Mount Rainier) format specifications were created and are maintained by the DVD+RW Alliance, a separate group of manufacturers established in 1997 by Philips Electronics, Hewlett-Packard, Mitsubishi Chemical, Ricoh, Sony and Yamaha. The DVD+VR and DVD+R Video application formats are the creation and responsibility of Philips Electronics.

Over the years many DVD physical formats have also developed into ECMA International and ISO/IEC standards. The composition of these manufacturer groups and standards bodies continues to change and expand.

DVD Physical Format Standards (ECMA International and ISO/IEC)

Format	Description	ECMA Standard	ISO/IEC Standard
DVD-ROM	80 mm disc	268 (Apr. 01)	16449:2002 (Apr. 02)
DVD-ROM	120 mm disc	267 (Apr. 01)	16448:2002 (Apr. 02)
DVD-R (G)	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	NA	NA
DVD-R (A)	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	NA	NA
DVD-R	120 mm & 80 mm disc (3.95 GB & 1.23 GB)	279 (Dec. 98)	20563:2001 (July 01)
DVD+R	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	349 (Dec. 03)	DIS 17344
DVD-RW	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	338 (Dec. 02)	DIS 17342
DVD+RW	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	337 (Dec. 03)	DIS 17341
DVD-RAM	120 mm & 80 mm disc case	331 (Dec. 01)	DIS 17594
DVD-RAM	120 mm & 80 mm disc (4.7 GB & 1.46 GB)	330 (June 02)	DIS 17592
DVD-RAM	120 mm disc case	273 (Feb. 98)	16825:1999 (May 99)
DVD-RAM	120 mm disc (2.6 GB)	272 (June 99)	16824:1999 (May 99)

What is the DVD-Video format?

DVD-Video (DVD-V) is an application format released by the DVD Forum in 1996. Originally designed to meet the requirements of the film industry for distributing commercial movies on prerecorded (pressed) discs, the DVD-Video format applies equally to writable DVD. Updates were undertaken in 2000 to officially accommodate DVD-R (General) and DVD-RW and again in 2001 for DVD-RAM. DVD-Video format can also be used with DVD+R and DVD+RW.

Typically, discs written in DVD-Video format can be played back using any DVD video player or computer DVD-ROM drive employing appropriate software (subject to that device's physical compatibility with the specific type of disc). Among its features, the DVD-Video format supports one main stream of video (MPEG-1, MPEG-2) with up to nine separate camera angles, as many as eight audio streams (Dolby Digital, MPEG-1, MPEG-2, LPCM, DTS), a maximum of 32 subpicture streams (graphic overlay) together with navigation menus, still images, simple interactivity, random accessibility plus many other extras.

Depending upon the capabilities of the computer installed DVD recorder, hardware and software used, DVD-Video format discs can be written using material transferred from either digital or analog sources. Digital material (such as video from a DV or writable DVD camcorder) is typically read directly from that device using an IEEE 1394 (FireWire/i.LINK) or USB interface and computer files (such as WMA, QuickTime, AVI, MPEG) from a hard drive. To record analog sources (such as VHS tapes, laserdiscs and cable broadcasts) signals are first digitized through a video capture card or similar IEEE 1394/USB unit. By using authoring software supporting the DVD-Video format, transferred material can sometimes be simply written to disc or processed into a more involved title employing creative tools and by adding further material.

Writable DVD camcorders as well as professional and consumer electronics (CE) recorders are all-in-one systems incorporating video and audio capture combined with authoring and disc writing. Typically, DVD-R and DVD-RW capable devices offer a "Video mode" selection to write those discs in DVD-Video format. Keep in mind that not all products exploit the full range of DVD-Video features and that there may be additional restrictions to consider. For example, it is generally not possible to partially write discs on one recorder and "finalize" them or add new material using a different recorder. Check with the manufacturer for specific details.

What are the DVD Video Recording, DVD+RW Video and DVD+R Video formats?

The DVD-Video format was initially designed to place static material on disc and not to seamlessly manage successive real time recording and editing from cable, satellite and other live video sources (like a VCR). To address this, several additional application formats were developed for use by consumer devices including writable DVD camcorders and consumer electronics (CE) recorders. The first of these is the DVD

Video Recording (DVD-VR) format released by the DVD Forum in 1999 for DVD-RW and DVD-RAM and later updated in 2000 to accommodate DVD-R (General). Philips Electronics then followed in 2001 and 2002 with its own DVD+RW Video (DVD+VR) and DVD+R Video formats for DVD+RW and DVD+R discs. Since many DVD-Video format features are not required for home recording applications, these formats offer an abridged selection of capabilities while adding some of their own.

Typically, DVD-RW and DVD-RAM capable recorders offer a “VR mode” selection to write those discs in DVD-VR format while DVD+RW and DVD+R recorders automatically write DVD+RW and DVD+R discs in the appropriate DVD+VR and DVD+R Video format. However, DVD-VR differs significantly from the original DVD-Video format. As a result, only devices specifically designed to be DVD-VR compatible (for example, units marked “RW compatible” and “DVD Multi”) can play DVD-VR recorded discs. DVD+VR and DVD+R Video closely resemble the DVD-Video format and, as such, maintain playback compatibility with most DVD devices. Keep in mind that not all products exploit the full range of features offered by these formats and that there may be additional restrictions to consider. Check with the manufacturer for specific details.

What is The Universal Disc Format (UDF)?

The Universal Disc Format (UDF) specification was first released by the Optical Storage Technology Association (OSTA) in 1995 and is designed to be a common logical file system for all removable optical storage media. Over the years various updates to UDF have been introduced to add new capabilities. So with DVD, UDF 1.02 is the standard file system used for DVD-Video, DVD-Audio and DVD-ROM prerecorded and writable discs. UDF 1.5 is frequently employed for incremental writing while UDF 2.0 applies to DVD-RW and DVD-RAM discs written in the DVD Video Recording (DVD-VR) format.

RECORDING HARDWARE

What types of devices record writable DVD discs?

The business, marketing and technology of writable DVDs have evolved over the years. There is now a wide variety of computer and consumer electronics (CE) devices available that record various versions and combinations of writable DVD disc formats (DVD-R, DVD-RW, DVD+R, DVD+RW, DVD-RAM). Product capabilities as well as marketing language and terminology vary widely so be careful to check with the manufacturer for specific details.

Examples of DVD Discs Writable by DVD Recorders

Recorder Type	DVD-R (Authoring)	DVD-R (General)	DVD-RW	DVD+R	DVD+RW	DVD-RAM
DVD+RW recorder	no	no	no	no	yes	no
DVD+R/+RW recorder	no	no	no	yes	yes	no
DVD±R/±RW recorder	no	yes	yes	yes*	yes	no
DVD-R (A) recorder	yes	no	no	no	no	no
DVD-R/-RW recorder	no	yes	yes	no	no	no
DVD-RAM recorder	no	no	no	no	no	yes** ***
DVD-RAM/-R recorder	no	yes	no	no	no	yes***
DVD Multi recorder	no	yes	yes	no	no	yes***
DVD Super Multi recorder	no	yes	yes	yes	yes	yes

* Some "Dual RW" recorders are not compatible with DVD+R discs.

** 2.6/5.2 GB DVD-RAM recorders are not compatible with 4.7/9.4 GB DVD-RAM discs.

*** Consumer electronics (CE) DVD-RAM, DVD-RAM/-R and DVD Multi recorders are not compatible with 2.6/5.2 GB DVD-RAM discs.

Are DVD video recorders available that connect to home theater systems?

A number of manufacturers offer consumer electronics (CE) and professional DVD video recorders that connect, like VCRs, to conventional video systems. Typically, they will only record to DVD from un-copy protected digital and analog sources (VCR, camcorder, internal hard disk drive, cable, satellite, laserdisc etc.).

Are writable DVD camcorders available?

Several manufacturers offer consumer digital camcorders that record video and still pictures directly to writable DVD discs. These units employ the smaller 8 cm disc size and can often be connected to a computer (typically using an IEEE 1394 or USB interface) to transfer material for editing as well as to be used as an external DVD recorder.

What do the numbers describing a DVD recorder mean?

Manufacturers typically use a sequence of numbers to express the maximum DVD and CD-R/RW writing and reading speeds of a recorder. Given the wide variety of possible format combinations and marketing approaches there are no established conventions as to the order of their presentation.

What types of computer DVD recorder configurations are available?

Whether for PC, Mac or UNIX systems in desktop, laptop or notebook form, computer DVD recorders are available in a wide variety of configurations to suit most needs. Several industry standard interfaces are available or forthcoming including SCSI, EIDE/ATAPI, USB, IEEE 1394 and Serial ATA for either internal or external recorder connection.

EIDE/ATAPI

The Enhanced Integrated Drive Electronics/ATA Packet Interface (EIDE/ATAPI) is the most popular method for connecting internal CD and DVD-ROM drives, hard disks as well as CD-R/RW and DVD recorders to a computer. Since most computers already have EIDE/ATAPI built-into their motherboards no additional interface card is necessary. These devices are normally installed internally but many external recorders are actually EIDE/ATAPI models employing bridge technology to convert them to SCSI, USB or IEEE 1394 interfaces.

SCSI

The Small Computer Systems Interface (SCSI) or “scuzzy” interface is a high performance and flexible method of connecting to a computer many peripherals including scanners, CD and DVD-ROM, hard drives as well as CD-R/RW and DVD recorders. In addition to long cable lengths, SCSI allows for both internal and external attachments. Some computers already have SCSI built into their motherboards, but, more often than not, a SCSI interface card is required. Some early DVD recorders made use of SCSI but most current units employ EIDE, USB or IEEE 1394 connections.

USB

The Universal Serial Bus (USB) is used to connect many types of peripherals to a computer including joysticks, mice, keyboards, printers, scanners, flash memory and external CD-R/RW and DVD recorders. Since USB is a plug and play interface computers do not have to be rebooted when a recorder is attached as these devices are automatically recognized by the system. USB has been updated several times to accommodate the demands of increasingly faster peripherals. While adequate for low speed CD-R/RW units the earlier USB 1.1 interface is not fast enough to keep up with DVD recording so that USB 2.0 is typically recommended. USB 2.0 interfaces are now built into the motherboards of most current systems but older computers may require an additional interface card.

IEEE 1394

Popularly known by trade names such as FireWire and i.LINK, IEEE 1394 is a high performance plug and play interface commonly used to connect computers to external hard disk drives, CD-R/RW and DVD recorders as well as consumer electronics (CE) devices like digital camcorders, game consoles and digital televisions. IEEE 1394 interfaces come standard on many Macintosh systems and on some brands of PCs but, more often than not, an interface card is required.

Serial ATA

Serial Advanced Technology Attachment (Serial ATA) is a new interface for connecting computers to internal storage devices such as hard disks, DVD-ROM drives and CD/DVD recorders. It is intended to eventually replace the current parallel ATA (EIDE/ATAPI) interface and will offer several advantages including longer and thinner cables with fewer pins, hot-plug capability, point-to-point connection (i.e. no master/slave relationship between devices) and a technology roadmap for future performance increases. Serial ATA interfaces are now built into the motherboards of many up to date systems but older computers may require an additional interface card.

Do computer DVD recorders write CD-R and CD-RW discs?

With near universal playback compatibility and low cost, CD-R and CD-RW discs are still excellent choices for a wide variety of data, audio and video applications. Consequently, in addition to writable DVDs, most current computer DVD recorders conveniently write CD-R and CD-RW discs (some older recorders may not be compatible with high, ultra and ultra speed plus CD-RW discs). However, this has not always been the case so, if in doubt, check with the hardware manufacturer.

RECORDING SPEED

How long does it take to record a writable DVD disc?

The amount of time taken to write a disc depends upon the writing speed of the recorder, the writing mode used by the recorder, the amount of information to be written and if verification or defect management is employed. Recording speed is measured the same as the reading speed of ordinary DVD-ROM drives and DVD players. At single speed (1x) a recorder writes 1.32 MB (1,385,000 bytes) of data per second and a multiple of that figure at each speed increment above 1x.

DVD Read and Write Average Data Transfer Rates (transfer rates indicated in binary notation)

DVD Read/Write Speed	Transfer Rate bytes/sec	Transfer Rate KB/sec	Transfer Rate MB/sec	Equivalent CD-R/CD-RW read/ write speed
1x	1,385,000	1,352.54	1.32	9x
2x	2,770,000	2,705.08	2.64	18x
3x	4,155,000	4,057.62	3.96	27x
4x	5,540,000	5,410.16	5.28	36x
5x	6,925,000	6,762.70	6.60	45x
6x	8,310,000	8,115.23	7.93	54x
8x	11,080,000	10,820.31	10.57	—
10x	13,850,000	13,525.39	13.21	—
12x	16,620,000	16,230.47	15.85	—
16x	22,160,000	21,640.63	21.13	—

Writing Modes

Building upon the advances made in CD-R and CD-RW technology writable DVD performance has progressed rapidly in a relatively short time. DVD recording speeds (data transfer rates) now surpass even their quickest CD-R and CD-RW counterparts. And, as with CD-R and CD-RW, DVD recorders employ a variety of writing modes to operate reliably and efficiently at both low and high speeds including Constant Linear Velocity (CLV), Zoned Constant Linear Velocity (ZCLV) and Constant Angular Velocity (CAV).

Constant Linear Velocity (CLV)

DVDs initially operated using a CLV mode to maintain a constant data transfer rate across the entire disc. The CLV mode sets the disc's rotation at roughly 1400 RPM decreasing to 580 RPM (1x CLV) as the optical head of the player or recorder reads or writes from the inner to outer diameter (ID to OD). Since the entire disc is written at a uniform transfer rate it takes, for example, roughly 57 minutes (excluding lead-in/lead-out) to complete a full 4.7 GB disc at 1x CLV. As recording speed increases the transfer rate increases correspondingly so that at 4x CLV writing a disc takes approximately 14 minutes. Recording time as well is directly related to the amount of information to be

written so partial discs will be completed in proportionally less time. But writing at higher speeds requires rotating the disc faster and faster (e.g. ID 8400 to OD 3480 RPM at 6x CLV) which places escalating physical demands upon both media and hardware. Manufacturers meet this challenge by moving beyond the CLV mode to obtain even higher performance.

Zoned Constant Linear Velocity (ZCLV)

In contrast to CLV which maintains a constant data transfer rate throughout the recording process, ZCLV divides the disc into regions or zones and employs progressively faster CLV writing speeds in each. For example, an 8x ZCLV DVD+R/+RW recorder might write the first 800 MB of the disc at 6x CLV and the remainder at 8x CLV speed. DVD-RAM (1x, 2x, 3x), on the other hand, uses a different form of ZCLV that divides the disc into many more regions (1.46 GB disc/14 zones, 2.6 GB disc/24 zones, 4.7 GB disc/34 zones). Here, rotational speed is kept constant within each zone but varies from zone to zone resulting in a roughly constant data transfer rate throughout the entire recording process.

Constant Angular Velocity (CAV)

The CAV mode spins the disc at a constant RPM throughout the entire writing process. Consequently, the data transfer rate continuously increases as the optical head writes from the inner to outer diameter of the disc. For example, a 5x CAV DVD-RAM recorder begins writing at 2x at the inner diameter of the disc accelerating to 5x by the outer diameter of the disc.

Verification and Defect Management

In addition to simply writing data, some recording software and hardware perform data verification or employ sophisticated defect management techniques, which can double the total amount of time to write the disc. Typically, data verification takes place after all data is written while defect management occurs during writing, actively verifying sectors and skipping over or relocating problems to a spare area of the disc. Data verification, a feature found in some recording software, works with most disc formats and often can be switched on or off. Both hardware (DVD-RAM, DVD+MRW) and software (UDF 2.0 formatted DVD-RW, DVD+RW and DVD-RAM) defect management is available and typically cannot be deactivated (consumer electronics DVD-RAM recorders typically do not implement defect management while, under certain circumstances, some computer DVD-RAM recorders may be able to partially disable this function).

Can writable DVD discs written at different speeds be read back at any speed?

The speed at which a disc is written has nothing to do with the speed at which it can be read back in a recorder, player or DVD-ROM drive.

How might DVD recording speeds increase in the future?

Product manufacturers have publicly discussed plans to increase DVD recording speeds to as high as 16x CAV. Achieving data transfer rates beyond this may be possible but is generally thought not to be practical given the technical challenges and cost considerations involved for minimal increases in real world performance. This is analogous to what happened with CD-R recording which, facing similar design (rotational speed capabilities of commercially available spindle motors) and market issues (high vibration and sound levels), effectively peaked at 52x/54x CAV speed.

PHYSICAL COMPATIBILITY

What types of devices read DVD-R and DVD+R discs?

Once written, single-layer (SL) DVD-R and DVD+R discs closely mimic the optical characteristics of single-layer (SL) prerecorded (pressed) DVDs. Thus, they can be read on the majority of computer DVD-ROM drives and DVD recorders. In addition, DVD-R and DVD+R discs are compatible with most consumer electronics (CE) DVD devices including portable, car and DVD players and recorders. Compatibility continues to evolve so newer devices are generally more able to play written discs. For example, some early DVD video players were released before the DVD-R specifications were completed so they do not recognize DVD-R discs. Some manufacturers suggest that under certain circumstances DVD+R can work around this issue by having the recorder write the disc using the prerecorded disc identification code thereby allowing the player to treat it as a pressed disc (see “DVD disc category” below). If in doubt, consult with the hardware manufacturer.

What types of devices read DVD-RW and DVD+RW discs?

Written DVD-RW and DVD+RW discs can be read on the majority of computer DVD-ROM drives and DVD recorders as well as consumer electronics (CE) DVD devices including portable, car and DVD players and recorders. However, DVD-RW and DVD+RW discs have optical signal characteristics (lower reflectivity) closer to those of dual-layer (DL) prerecorded (pressed) DVDs which sometimes contributes to incompatibilities (see “DVD disc category” below). As with DVD-R and DVD+R, compatibility continues to evolve so some devices (typically older) may not be able to play written discs. If in doubt, consult with the hardware manufacturer.

What types of devices read DVD-RAM discs?

DVD-RAM discs are significantly different from prerecorded DVDs (data in land and groove areas, embossed sector headers, lower reflectivity and signal modulation, hardware-based defect management, optional cartridge, etc.). As a result, only devices specifically designed to be DVD-RAM compatible can read DVD-RAM discs. These include DVD Multi-compliant computer and consumer electronics (CE) drives, players and recorders as well as other DVD-RAM recorders and DVD-ROM drives expressly supporting DVD-RAM. Keep in mind that not all devices accommodate cartridge discs. As well, there have been several generations of DVD-RAM technology so previous and current versions of discs and devices may not be compatible with one other. Specifically, early DVD-RAM recorders and DVD-RAM compatible DVD-ROM drives read only 2.6 GB single-sided (SS) and 5.2 GB double-sided (DS) discs. In addition,

DVD Multi-compliant and DVD-RAM consumer electronics (CE) recorders and players cannot read 2.6 GB (SS) and 5.2 GB (DS) discs. If in doubt, consult with the hardware manufacturer.

What is DVD Multi?

The DVD Forum created the DVD Multi specification in 2001 to provide hardware manufacturers with the requirements necessary to make computer and consumer electronics (CE) DVD devices read or read and write most DVD disc formats sanctioned by the DVD Forum. Specifically, the DVD Multi specification requires that DVD Multi Players read DVD-ROM (prerecorded), DVD-R (General), DVD-RW and DVD-RAM discs and DVD Multi Recorders read and write those same formats. Be aware that DVD Multi does not prescribe that devices should accommodate DVD-RAM cartridges or 8 cm discs. If in doubt, consult with the hardware manufacturer.

Examples of Discs Readable and Writable by DVD Multi Compliant Drives, Players and Recorders

Type of Disc	DVD Multi Player	DVD Multi Recorder
DVD-ROM (prerecorded)	read	read
DVD-R (General)	read	read/write
DVD-RW	read	read/write
DVD-RAM	read*	read/write*

* DVD Multi consumer electronics (CE) devices are not compatible with 2.6/5.2GB DVD-RAM discs.

What is the “DVD disc category” and how can it affect playback compatibility?

Contained within the Lead-In Area of a DVD disc is information about its physical format including its “disc category” (also known as “book type”). This refers to the kind of disc it is as defined by one of the many DVD Forum specifications or “books”. Currently, there are four categories — prerecorded (pressed) DVD, DVD-RAM, DVD-R and DVD-RW. DVD Forum specifications do not govern DVD+R and DVD+RW therefore these discs use other categories.

Playback problems can arise (typically in some older devices) if the playing unit is programmed to ignore the category information or to accept only prerecorded discs or the four DVD Forum defined types. To potentially improve the playback compatibility of DVD+R and DVD+RW discs in such devices some DVD recorders are designed to write, or optionally write, these discs with the prerecorded (pressed) category code. Since DVD+RW discs are rewritable various routines (for consumer electronics recorders) or software (for computer recorders) are sometimes made available that can rewrite the disc category code in both its native DVD+RW and the prerecorded setting.

Not all DVD+R/+RW compatible recorders support making these changes and, in general, manufacturers advise against changing a disc's category setting unless this specific playback problem is encountered and others recommend against this practice entirely.

DVD Disc Categories

Disc Format	Disc Category	Disc Specification Source
Prerecorded (pressed) DVD	0	DVD Forum
DVD-RAM	1	DVD Forum
DVD-R	2	DVD Forum
DVD-RW	3	DVD Forum
DVD+RW	9	DVD+RW Alliance
DVD+R	10	DVD+RW Alliance

DISC SIZE, CONFIGURATION AND CAPACITY

What are the physical sizes of writable DVD discs?

Generally, writable DVD discs come in 12 cm (120 mm) and 8 cm (80 mm) diameter sizes. The most commonly used is the larger 12 cm type which has the same physical dimension as most commercial video, audio, computer software and game console DVDs. 8 cm discs are less common and are typically used in portable consumer electronic devices such as digital video camcorders.

What configurations of writable DVD discs are available?

Currently, writable DVD discs are single-layer (SL) products which can either be single (SS) or double-sided (DS). Single-sided discs are used in everyday data and video applications while double-sided discs are more specialized (largely due to the lack of a convenient labeling surface) and are typically employed in automated storage jukeboxes and in writable DVD camcorders. In addition, DVD-RAM discs come as bare or can be enclosed in protective “cartridges”. Some types of these cartridges may be opened to allow the discs to be removed while others come permanently sealed. Be aware that not all DVD-RAM compatible drives, players and recorders accommodate cartridge discs.

DVD-RAM Disc Cartridge Configurations

Size	Sealed Cartridge		Removable Disc		Empty Cartridge	
	Single-sided	Double-sided	Single-sided	Double-sided	Single-sided	Double-sided
8 cm	—	—	Type 7 (1.46 GB)	Type 6 (2.92 GB)	Type 9 (1.46 GB)	Type 8 (2.92 GB)
12 cm	Type 1 (2.6 GB, 4.7 GB)	Type 1 (5.2 GB, 9.4 GB)	Type 2 (2.6 GB, 4.7 GB)	Type 4 (5.2 GB, 9.4 GB)	Type 3 (2.6 GB, 4.7 GB)	Type 5 (9.4 GB)

Are dual-layer writable DVD discs available?

Manufacturers are developing 8.5 GB single-sided (SS) dual-layer (DL) DVD+R and DVD-R discs for release sometime in 2004 or 2005. Although they approximate dual-layer prerecorded DVD-9 discs be aware that, due to various technical issues, such writable discs may not be read compatible with some older computer DVD-ROM drives and DVD players and they will not be write-compatible with older recorders. If in doubt, check with the hardware manufacturer.

What capacities of blank writable discs are available?

Manufacturers express disc capacity in terms of how much computer data a disc can contain. DVD-R (General), DVD-R (Authoring), DVD+R, DVD+RW and DVD-RAM discs come in 4.7 GB single and 9.4 GB double-sided (12 cm) and 1.46 GB single and 2.92 GB double-sided (8 cm) sizes.

This has not always been the case for DVD-RAM and DVD-R. DVD-RAM discs designed for use in early recorders (version 1.0) come in 2.6 GB single-sided and 5.2 GB double-sided (12 cm) sizes. DVD-R discs compatible with first generation recorders (version 1.0) come in 3.95 GB single-sided and 7.9 GB double-sided (12 cm) and 1.23 GB single-sided and 2.46 GB double-sided (8 cm) sizes.

Keep in mind that manufacturers quote the capacity of a writable DVD disc in decimal (base 10) rather than binary (base 2) notation so a 4.7 GB disc stores 4.7 billion bytes [4,700,000,000 bytes ÷ 1000 = 4,700,000 KB ÷ 1000 = 4,700 MB ÷ 1000 = 4.7 GB]. Expressed in binary notation (as is typical with CD-R, CD-RW and most operating systems) the same disc has a capacity of roughly 4.38 GB [4,700,000,000 bytes ÷ 1024 = 4,589,844 KB ÷ 1024 = 4,482.27 MB ÷ 1024 = 4.38 GB].

How much information can actually be stored on writable DVD discs?

The amount of information that can be written is determined by the disc's recording capacity as well as the physical and logical formats used.

All writable DVD formats devote the same amount of usable space to data (2,048 bytes per sector). DVD+R, DVD+RW and DVD-RAM specify the number of sectors available for user information (1.46 GB DVD+R/+RW 714,544 sectors, 4.7 GB DVD+R/+RW 2,295,104 sectors, 1.46 GB DVD-RAM 714,480 sectors, 2.6 GB DVD-RAM 1,218,960 sectors, 4.7 GB DVD-RAM 2,295,072 sectors) so disc capacity can be calculated by multiplying the user data area size by the number of disc sectors. For example, a 4.7 GB DVD+R disc: 2,048 bytes/sector x 2,295,104 sectors = 4,700,372,992 bytes. This rounds to roughly 4.7 GB (decimal notation).

DVD-R and DVD-RW, on the other hand, do not stipulate the number of sectors that are dedicated to user information but simply that a minimum capacity must be available on the disc. In the case of DVD-R (version 1.0) this is 3.95 (12 cm) and 1.23 (8 cm) billion bytes and for DVD-R (Authoring), DVD-R (General) and DVD-RW 4.7 (12 cm) and 1.46 (8 cm) billion bytes. Consequently, real world capacity can vary slightly among discs from different media manufacturers although many have informally settled on 2,298,496 sectors (4,707,319,808 bytes) for a DVD-R (General) 4.7 GB disc.

Writable DVD Disc Capacities
(Unformatted Single-Sided, Single-Layer Discs)

Disc Format	Specification Version	Disc Size	Number of User Data Sectors Per Side	Gross Capacity (bytes)
DVD+R	1.2	8 cm	714,544	1,463,386,112
		12 cm	2,295,104	4,700,372,992
DVD+RW	1.2	8 cm	714,544	1,463,386,112
		12 cm	2,295,104	4,700,372,992
DVD-R	1.0	8 cm	600,586	1,230,000,000
		12 cm	1,928,711	3,950,000,000
	Authoring 2.0	8 cm	712,891	1,460,000,000
		12 cm	2,294,922	4,700,000,000
General 2.0	8 cm	712,891	1,460,000,000	
	12 cm	2,294,922	4,700,000,000	
DVD-RW	1.1	8 cm	712,891	1,460,000,000
		12 cm	2,294,922	4,700,000,000
DVD-RAM	1.0	12 cm	1,218,960	2,496,430,080
	2.0	12 cm	2,295,072	4,700,307,456
	2.1	8 cm	714,480	1,463,255,040

Be aware, however, that the logical format (UDF, FAT, HFS etc.) as well as any defect management system employed consume space otherwise available for user information. For example, DVD-RAM can dedicate as much as 184 MB (192,937,984 bytes) on a 1.46 GB disc, 126.86 MB (133,022,816 bytes) on a 2.6 GB disc and 216 MB (226,492,416 bytes) on a 4.7 GB disc for defect management while Mount Rainier formatted DVD+RW (DVD+MRW) can allocate up to 128.75 MB (135,000,000 bytes) on a 1.46 GB disc and 515.94 MB (541,000,000 bytes) on a 4.7 GB disc.

How many minutes of video can be stored on writable DVD discs?

In contrast to CD technology where Red Book audio or Video CD specifications rigidly prescribe the amount, type and quality of material a disc contains, the DVD-Video format is flexible, permitting content to be housed in different forms and levels of quality. Consequently, the number of minutes of audio and video that can be stored on a writable DVD disc varies considerably.

In terms of its basic capabilities, the DVD-Video format supports one main stream of video (MPEG-1, MPEG-2) with up to nine separate camera angles, as many as eight streams of audio (Dolby Digital, MPEG-1, MPEG-2, LPCM, DTS, SDDS), a maximum of 32 subpicture streams (graphic overlay) as well as navigation menus and other extras. Each of these occupy space so the amount of material that can be recorded depends upon the number of features incorporated, the type and degree of audio and video compression used and the capacity of the disc. For example, a single-sided 4.7 GB disc holds roughly one hour of straightforward audio and video at maximum DVD quality and

a 1.46 GB disc approximately 18 minutes. At the other end of the spectrum, the same discs might accommodate as much as nine hours and three hours respectively of VHS quality material.

Not all computer video and audio encoding systems, authoring software and consumer electronics (CE) recorders offer access to all DVD-Video features or support all degrees of compression. Thus, in practice, different products offer a range of possible recording times. For example, an entry-level DVD-Video authoring software package might support only limited features and permit only one hour of recording (using as little compression as possible) to keep the quality of the final result as high as possible. Mid-range and professional hardware and software tools provide the greatest degree of freedom while consumer products generally offer the least.

Generally speaking, consumer electronics (CE) recorders have a variety of automatic or manual recording modes typically ranging from one to four hours (occasionally six to eight hours) per 4.7 GB disc while writable DVD camcorders usually offer between 20 minutes to one hour per 1.46 GB disc. Although manufacturers sometimes use language such as High Quality (HQ), Standard Play (SP), Long Play (LP) and others to describe the recording time of their products, be aware that there are no broadly accepted industry standards for the use of such terminology.

COPYING DETERRENTS AND CONTENT PROTECTION

Can commercial DVD-Video and DVD-Audio discs be copied onto writable DVDs?

To deter users from making disc-to-disc and other direct digital copies of commercial movies and audio albums, most prerecorded DVD-Video and DVD-Audio format discs are protected at the factory using (respectively) the Content Scrambling System (CSS) and Content Protection for Prerecorded Media (CPPM).

CSS and CPPM selectively encrypt disc sectors that can only be decrypted during playback by licensed products (DVD players, computer DVD playback software and others). Critical information (decryption keys, album identifiers) required to unlock content is located in protected regions of these discs (Control Data Zone of Lead-in Area and sector headers) accessible to the player or drive and under only carefully regulated circumstances. Without these keys the encrypted video or audio is unusable. Performing bit-for-bit duplication or simply copying files from the disc to a writable DVD, hard drive or other storage medium will not yield a useful reproduction.

As a further defense, writable DVD products employ several safeguards to prevent valid CSS decryption keys and CPPM album identifiers from ever being written to these discs. For example, blank writable DVD discs come from the factory with the Control Data Zone of their Lead-in Areas already “prewritten” (DVD-R General) or embossed (DVD-RW, DVD-RAM) with dummy information. And, in the case of DVD-R (version 1.0), DVD-R (Authoring), DVD+R and DVD+RW, recorders are designed to write only dummy information in the same disc area (and sector headers). This also inhibits CSS or CPPM protection being conferred on content recorded on writable DVD discs for professional or other applications.

Nevertheless, over the years various computer software tools have emerged to allow the making of copies of CSS protected DVD-Video discs.

COPYRIGHT LAW must always be respected whenever dealing with content of any type. Products that bypass protection systems are not permitted in most jurisdictions. And even if a disc lacks content protection it does not mean that copying is permitted. OSTA does not support the use of writable DVD products for any unlawful purpose.

What is region management?

In addition to employing technology to discourage copying, CSS-encrypted DVD-Video discs may optionally contain region management information to allow commercial movie publishers to control the distribution of their products throughout the world. Discs (so enabled) and players contain information that specifies the geographic areas where they are to be marketed. To prevent discs intended for sale in one part of the world

being distributed and used elsewhere all devices automatically check discs for region codes and only play titles for which they are authorized.

For computer DVD-ROM drives and recorders this task is accomplished through Regional Playback Control (RPC) of which there have been two phases. Phase I implementations were used prior to the end of 1999 and function through the computer's video playing software, decoding system or operating system to manage region control. In this case, the region code could be set only once and, for some decoders, the region was sometimes even preset at the factory. Phase II implementations have been in use since 2000 and hand-off responsibility for region management exclusively to the drives and recorders implementing the necessary functions in their firmware. Generally speaking, the user can change the region code up to five times with the manufacturer having the additional ability to then service the unit and reset this counter (up to four times).

Assorted workarounds to region management exist in the marketplace (typically outside North America) including "multi-region" DVD players that read discs regardless of region codes. As well, altered computer DVD-ROM drive and DVD recorder firmware is sometimes circulated to achieve the same effect. Be aware, however, that such modifications can invalidate product warranties.

DVD-Video Region Codes (Simplified)

Region Code	Geographic Region
1	United States, Canada
2	Japan, Europe, Middle East, South Africa
3	South East Asia (including Hong Kong)
4	Australia, New Zealand, Mexico, Central and South America
5	Northwest Asia, North Africa
6	China
7	Unassigned
8	Special purpose (aircraft, cruise ships, hotels)

What is Content Protection for Recordable Media?

Sometimes analog or digital broadcasts (typically in Japan) are identified to allow only one copy to be made by a viewer and by using the Content Protection for Recordable Media (CPRM) system, such material can be encrypted and recorded once to a writable DVD disc. As it is currently marketed, CPRM is an option found only in some consumer electronics (CE) DVD recorders that write DVD-RW and DVD-RAM discs using the DVD Video Recording format (DVD-VR). This allows material specifically flagged "copy once" to be written to a single disc but prevents that disc from then being further duplicated. This is accomplished by binding the content to the particular disc through encryption

employing, among other things, a code (media identifier) unique to each writable disc compliant with the CPRM system. This one-off code is inserted at the factory into the special Narrow Burst Cutting Area (NBCA) of a DVD-RW or Burst Cutting Area (BCA) of a DVD-RAM disc and, as such, cannot be duplicated by a DVD recorder.

Be aware that not all DVD players, drives and recorders that play or write DVD Video Recording formatted (DVD-VR) discs are compatible with CPRM and that not all blank DVD-RW and DVD-RAM discs are equipped with the NBCA or BCA necessary to handle CPRM content. If in doubt, consult with the hardware or disc manufacturer.

DUPLICATION, REPLICATION AND PUBLISHING

What alternatives are available to duplicate DVDs?

There are several different methods available to make one or multiple copies of existing DVDs ranging from single DVD recorders to specialized devices that automatically duplicate and label discs and, for large runs, commercial mass replication. Options are distinguished by cost, speed, convenience and capability. Some of the many applications include reproducing previously created DVD home movies, circulating in-house corporate software, updates and training videos, making backup copies for off-site storage and even commercially distributing software, audio and DVD-Video titles.

As previously stated in this white paper, it is essential to always investigate and obey COPYRIGHT LAWS whenever dealing with content of any type and be aware that products that bypass content protection systems are not permitted in most jurisdictions. Also keep in mind that one is not necessarily authorized to copy a disc even if it lacks content protection measures. OSTA does not support the use of writable DVD for any unlawful purpose and that all DVD products should be used only for legal purposes.

Computer DVD Recorders

By far the quickest and least expensive way to duplicate a disc is to copy it using a computer outfitted with a DVD recorder combined with off the shelf writing software. In addition to creating discs from scratch, many basic writing software packages will duplicate most standard DVD formats. Specialized copying software is also available with more sophisticated capabilities such as the ability to simultaneous duplicate to multiple recorders. But remember that the ability of a system to copy specific disc formats depends upon the individual capabilities of the software, reader and recorder used. It is therefore advisable to check with the respective manufacturers for specific information.

Typically, discs are duplicated DVD to DVD by using the computer's DVD-ROM drive as the master source feeding the copying recorder. In cases where a separate reading drive is not available the master is first downloaded to the computer hard drive using the reading ability of the recorder and later written back to a blank disc using the same recorder. Employing the computer's hard disk as an intermediate copying step is also a common tactic used when dealing with poor quality source discs or other situations where computer systems are not fast enough to keep up to the speed set on the recorder.

DVD Duplication Systems

For copying larger numbers of discs various dedicated DVD duplication solutions are available including machines that function by themselves or with the assistance of operators. These configurations can either sit as standalone units or may be attached as computer peripherals. The most common devices are hand-fed tower systems that employ a number of DVD recorders linked together for simultaneous duplication from

either a master DVD or from a hard drive. Also widely used are automated products incorporating robotic disc handling systems that mechanically load and unload one or more recorders. Sometimes disc label printers are included to produce a handful or even dozens of finished discs per hour. In addition to large commercial solutions many DVD duplication systems are compact and affordable and within reach for personal and office use. A number of companies also offer commercial DVD duplication services to perform short run work in quick turnaround times.

DVD Mass Replication

In contrast to DVD duplication which is usually performed on a small scale at the desktop level, DVD mass replication is typically used to make huge quantities of discs such as commercial DVD movies and software DVD-ROMs. These prerecorded (pressed) discs are manufactured from a mold in a factory setting and are created using a complete series of industrial processes including premastering, mastering, electroplating, injection molding, metallization, bonding, spin coating, printing and advanced quality control. In addition to manufacturing discs, many replication companies offer companion services including packaging, printing, distribution and fulfillment.

What is DVD publishing?

Somewhat like DVD duplication equipment, DVD publishing systems employ DVD recorders but are used to create quantities of unique discs from different computer files rather than just to make multiple copies of a single master disc. Employing robotic disc handling systems and integrated label printers, many of these devices can be accessed over computer networks and shared much like office laser printers. Examples of DVD publishing applications include creating writable DVDs containing medical images or monthly banking records, archiving computer-generated billing records to disc in place of microfilm and accepting conventional analog video tapes resulting in DVD video on writable DVD discs.

Is it possible to transfer the contents of a DVD-9 video disc onto a writable DVD?

Writable DVD discs are currently single-layer (SL) products that accommodate a maximum of 4.7 GB of information per side. Prerecorded (pressed) DVD discs, on the other hand, can contain up to 8.5 GB of data on one side by using dual layers (known as DVD-9). Several techniques can be used to place the larger contents of a DVD-9 DVD-Video format disc onto writable DVDs. These include splitting the material onto two discs or re-authoring it to fit onto one. For example, by using various software programs disc content can be broken into pieces or supplementary material deleted so only the main video segment remains to fit onto a single writable DVD disc. Such software can sometimes recompress the video content to a lower bit rate to fit onto one

disc. In this case excluding extraneous material lessens the required amount of recompression to maintain higher video quality. As stated earlier in this white paper, COPYRIGHT LAW must always be respected.

Is it possible to copy one writable DVD disc type onto another?

Depending upon the capabilities of the hardware and software used it is possible to copy one writable DVD disc type onto another (for example, copying the contents of a DVD+RW disc to a DVD-R disc). Be aware, however, that there are slight capacity differences among the various types that might make the contents of one disc too large to fit onto a disc of another type. As well, some application formats may be untested or inappropriate for use with certain types of discs.

DISC LABELING

What alternatives are available to label writable DVD discs?

There are several different labeling methods available for writable DVD discs ranging from hand writing, to adhesive labels, specialized devices that print directly onto the disc surface and ultimately the various commercial printing solutions. Options are distinguished by cost, speed and convenience as well as by durability and the visual quality of the result. But keep in mind that applying any kind of label modifies the disc in some significant way. Thus, product warranties can be invalidated and unforeseen consequences may arise. It is, therefore, advisable to always follow disc, recorder, drive and player manufacturer directions.

Hand Writing

By far the quickest and least expensive way to label a disc is to simply write on its top surface. Using a soft fiber or felt-tipped permanent marker is preferable but be aware that the solvents in some types of inks can potentially damage the disc and, even though the plastic dummy substrate of a single-sided writable DVD disc affords some protection, caution is still in order. Avoid using ballpoint pens, pencils or other sharp writing instruments. As with CD-R and CD-RW the part of the disc least vulnerable to injury is the center clamping or hub area. Double-sided writable DVD discs can be marked only in this region. Some discs are specially coated to accommodate handwritten labels and even special markers are available and intended for such use.

Adhesive Labels

A more attractive way to label a disc is to apply an adhesive label. Several manufacturers offer permanent marker, inkjet, solid ink and laser printer compatible products specifically designed for labeling discs as well as positioning devices to help with centering. Other options include various surface colors and finishes including matte, glossy, foil, holographic and glow in the dark as well as special coatings that can be repeatedly written on with permanent marker and dry erased. Full surface or “donut-style” labels are preferable to partial stickers but be careful as any adhesive label can potentially upset the balance of a disc when playing back. This is especially true at high speeds, resulting in excessive noise, vibration and data retrieval problems. Heat, humidity, sunlight, handling and the passage of time can also compromise the stability of adhesive labels resulting in separation from the disc surface and even interference with the drive. Sticky labels may not be the best choice when archiving important data as some types of label adhesives can react with and undermine the disc over time. Remember too that, once applied, labels should never be removed or repositioned. Even smoothing air bubbles can concentrate physical stresses in a small area and potentially damage the disc.

Specialized Disc Printers

Specialized disc printing devices are available to label discs in larger numbers and for imparting a more polished appearance. Currently, desktop products employing inkjet, thermal transfer and re-transfer technologies are available for directly labeling on the disc surface.

Inkjet

Inkjet printing technology has been available for many years and has proven extremely popular with consumers due to its high quality and cost effectiveness. Inkjet printers function by ejecting liquid ink from a print head onto the surface of a specially coated “inkjet-printable” disc. These special discs have an extra coating, called an Ink Absorption Layer (IAL), which receives the ink from the printer and allows it to stay in place long enough to properly dry. Some discs are even available decorated with screen printed images and areas left blank for desktop inkjet labeling. Inkjet printers produce high-resolution full color images but there is a downside in that resulting labels are subject to being smudged by high humidity or damp fingers and thus are not suitable for use in automotive or other harsh environments. Inkjet printed discs should not be stored or shipped in flexible plastic envelopes as the chemicals used to keep the package materials supple can interact with the inks and cause the label to stick to the sleeve resulting in additional physical stresses upon disc removal. Using jewel cases or other containers that do not directly contact the printed surface is best.

Thermal Transfer

Unlike inkjet printers that spray liquid ink, thermal transfer printers convey solid pigment from a coated ribbon onto the surface of a disc through a combination of heat and pressure. Typically used to produce monochrome and spot color labels, thermal transfer printing does not require specially coated discs to accept the ink from the printing process. The results are, as well, reasonably durable. However, some disc surfaces give better results than others. Consequently, discs are available which feature special coatings optimized for thermal transfer printing. But be aware that writable DVD discs often have a raised ring in their center hub or clamping area that interferes with and can damage the printer’s labeling head. It is possible to print above and below this area to avoid the difficulty and there are some discs specially manufactured without this ring to provide an unobstructed surface. For labeling situations where discs share a largely common background appearance but vary slightly from disc to disc or among groups of discs some thermal transfer solutions can align and overprint their output onto partial images already printed onto the surface of the disc.

Re-transfer

More recently, re-transfer printers have come to market and function by applying heat and pressure to convey solid resins from an ink ribbon to an intermediate film and then to the surface of the disc. Typically re-transfer systems produce photo-realistic color labels that are smooth and highly durable. Only certain types of disc surfaces are suitable for re-transfer printing including those optimized for thermal transfer use as well as some inkjet-printable surfaces and “crystal” protective coatings. Some additionally offer coated center hubs that allow for full surface printing.

Commercial Printing

Various methods are used to commercially decorate discs including screen, offset, pad and flexographic printing. These are large-scale industrial processes typically used to label large numbers of discs with the same pattern or in situations when precise color matching is required for critical items such as company logos. In addition to desktop disc labeling, many duplication companies and replicators offer commercial printing services.

Can labels produced on inkjet-printable discs be made more water resistant?

Several different methods can be used to improve the durability of labels produced on inkjet-printable discs. Various products are available which apply materials to coat or seal the surface of the disc to provide a more robust barrier against moisture and handling. In addition, such solutions can impart different finishes (such as gloss or matte) and, in the case of overlaminates, possibly attach a stock or custom hologram to enhance label appearance and authenticate a disc to help deter counterfeiting.

DISC HANDLING, STORAGE AND DISPOSAL

What is the best way to handle and store a writable DVD disc?

A disc should always be handled by grasping its outer edges, center hole or center hub clamping area. Avoid flexing or dropping the disc and exposing it to direct sunlight, excessive cold, heat or humidity. Handle only when being used and do not eat, drink or smoke close by. Discs should be stored in DVD jewel cases or video boxes rather than sleeves because cases will not contact the discs' surfaces and generally provide better protection against scratches, dust, light and rapid humidity changes. CD jewel cases can stress DVDs by gripping them too tightly resulting in discs being difficult to remove from CD cases without excessive flexing. As a result, use only containers specifically designed for DVDs and discs should always be removed carefully. Once placed in their cases discs can be further protected by keeping them in a closed box, drawer or cabinet. For long-term storage and archival situations it is advisable to follow manufacturer instructions. For further information consult the international standards for preserving optical media (ISO 18925:2002, Imaging materials — optical disc media — storage practices).

Should fingerprints and dust be cleaned off a writable DVD disc?

Like CD, DVD technology is robust and employs several design elements to minimize the effects of fingerprints and minor scratches on data integrity. The first line of defense comes from the physical structure of the disc and the location of the data-bearing marks and lands. The reading laser beam shines through the disc's substrate focusing beyond the contaminated surface directly onto the marks and lands beneath. In concert with advanced error detection and correction capabilities minor debris and abrasions are largely ignored. That said, handling care should always be taken as above. A dusty disc should be blown off so that the dust does not enter the drive mechanism and accumulate on the lens or other optical components. It should be noted as well that fingerprints, dust and scratches have a greater impact on recording than is the case with reading a disc since contaminants reduce the effectiveness of the writing laser by obscuring its beam from the disc's recording layer.

What is the best way to clean a writable DVD disc?

Dirty discs should be carefully cleaned using a soft dry lint-free cloth or camera lens tissue. Holding the disc by its outer edges or center hole gently wipe outward from the center hub toward the outside edge of the disc (just like the spokes of a bicycle wheel). Do not wipe the disc using circular motions, as any scratches created will do the least damage if they cut across the track of marks and lands. More stubborn fingerprints or stains can be removed using a soft lint-free cloth lightly moistened with water or a

commercially available DVD/CD cleaning fluid. Do not use vinyl record cleaners, lacquer thinner, gasoline, kerosene, benzene or other solvents, as these may damage the disc. Manufacturer directions should always be followed.

Can scratched and damaged writable DVD discs be restored?

Often it is less expensive and makes more sense to transfer the data from a damaged disc onto a new one rather than to try to restore the problem disc. For dealing with more badly damaged situations consumer disc repair kits are available and several companies offer DVD restoration and resurfacing equipment and services. See the resource listing in the appendix for contact information.

Is it possible to recover data from damaged writable DVD discs?

Several software packages are currently available to diagnose disc problems and help recover deleted, unreadable or otherwise inaccessible information. A number of companies also offer commercial DVD data recovery services. See the resource listing in the appendix for contact information.

What is the best way to destroy unwanted writable DVD discs?

For office and high volume production situations various DVD destruction options are available including mechanical shredders, desktop devices that employ heat and pressure to make a disc unreadable and grinders that abrasively remove the disc's reflective and data-bearing recording layers. Unlike a CD where data is physically located close to the disc's top or label side, information recorded on a DVD resides in its interior. Consequently, not all devices that destroy CD-R and CD-RW discs are capable of properly dealing with writable DVDs. A number of companies offer commercial destruction services and deal with classified or other sensitive materials. See the resource listing in the appendix for contact information.

Can unwanted writable DVD discs be recycled?

A number of companies offer DVD recycling services and are able to reclaim some of the materials used in the disc's construction. See the resource listing in the appendix for contact information.

DISC LONGEVITY

How many times can a DVD-RW, DVD+RW and DVD-RAM disc be rewritten?

As is the case with other optical storage media using phase-change technology there is a limit to the number of times the recording layer in a DVD-RW, DVD+RW and DVD-RAM disc can be reliably switched between its crystalline and amorphous states. It is estimated that a DVD-RW or DVD+RW disc can be rewritten approximately 1000 times and a DVD-RAM 100,000 times. In addition, these formats (under certain circumstances) employ defect management schemes to actively verify data and skip over or relocate problems to a spare area of the disc.

How long will data recorded on writable DVD discs remain readable?

The life span of a written disc depends upon a number of factors including such things as the intrinsic properties of the materials used in the disc's construction, the quality of its manufacture, how well it is recorded and the way it has been handled and stored. As a result, the life span of a recorded disc is extremely difficult to estimate reliably. However, to calculate disc life spans within some practical timeframe blank media manufacturers conduct accelerated age testing by subjecting samples of their discs to environments much beyond those experienced under normal storage conditions. Generally speaking, these tests only consider the effects of varying temperature and humidity. Results are then used to predict how long a disc will remain readable under more normal storage conditions. Questionable testing and measurement procedures can seriously impact upon and compromise these estimates so keep in mind that unlike prerecorded (pressed) CD and CD-R discs there are currently no international standards for conducting writable DVD accelerated testing. Writable DVDs and CDs may appear similar, but their construction and underlying design differ significantly so what applies to the one does not necessarily apply to the other.

As with CD-R and CD-RW discs media manufacturers have performed their own lifetime evaluations using a variety of homegrown tests and mathematical modeling techniques. Generally speaking, manufacturers claim life spans ranging from 30 to 100 years for DVD-R and DVD+R discs and up to 30 years for DVD-RW, DVD+RW and DVD-RAM. Be aware, however, that disc producers, manufacturing methods and materials change over time as do applications and cost imperatives. Consequently, those concerned with disc longevity should consult their media manufacturer for more particular information.

One thing is sure — nothing lasts forever and technologies inevitably change. Ultimately, since writable DVDs embody digital information, contents may be transferred to future storage systems as becomes necessary to preserve whatever has been stored on the discs.

DISC TESTING AND VERIFICATION

Is it necessary to verify a writable DVD disc after recording?

Verifying a disc after recording helps to maintain an appropriate quality level. The amount of ongoing integrity checking and data verification that may be prudent is really a question of acceptable risk for any particular application. For example, letting recording software conduct data comparisons immediately after writing is usually sufficient in casual situations but critical data archiving and large-scale duplication may call for more comprehensive testing. This is due to the differences that often exist among recorders, drives and players. Consequently, successfully verifying a written disc on only a recorder does not guarantee broad playing compatibility, especially in cases where a disc is of marginal quality.

How can the quality of a recorded DVD disc be assessed?

Several methods can be used to assess the quality of a written disc. These include measuring its optical signals, examining the integrity of its physical and logical formats, performing interchange testing and conducting data verification. Each method is a piece of the quality testing puzzle. The extent to which a disc needs to be tested depends, of course, upon the imperatives of the application.

At a basic level it is possible to confirm that information has been correctly written to a disc by comparing it against the source material using the verification features found in many off-the-shelf writing software packages. When more detailed analysis is warranted, interchange testing can be performed to provide some practical indication of real-world compatibility. To accomplish this, DVD-Video discs are played back in a number of consumer electronics (CE) DVD video players and computer DVD-ROM drives to check for quality issues while data discs are checked in a variety of DVD-ROM drives to make sure that recorded information is completely recoverable and at speeds established by the manufacturers. Specialized computer software controlling everyday DVD-ROM drives can also be used to read a disc at a lower level of organization to verify that its physical and logical formats conform to industry specifications. In all cases it is assumed that the testing tool used broadly represents the behavior of the general population of reading and playing devices in the market. However, this may or may not be a valid assumption given the wide variety of readout optical systems and the error detection and correction (EDAC) circuitry and strategies in use.

For situations that require appraising more fundamental physical characteristics, a number of commercial analysis tools are available to examine the optical signal characteristics of a recorded disc and thus identify low-level errors. Typically, these devices are standalone or computer-attached and employ DVD-Video or DVD-ROM drives specially modified to measure various disc parameters and provide descriptive reports. As is the case in testing generally, results can vary significantly among

inspection systems. To maintain continuity, therefore, discs should always be evaluated on the same piece of equipment. Commercial DVD testing companies offering quality verification services using such devices are also widely available. The accuracy and usefulness of commercially available test platforms (other than those produced by a few semi-officially sanctioned manufacturers) are often debated in technical circles. Consequently, the results such systems generate should be viewed cautiously as it is unclear what they mean in the larger context of reliability and in determining conformance to established specifications.

An important question that has always existed for optical disc testing is the uncertainty of the relationship between the results derived from evaluating discs on low-level analyzers and real world disc performance in the installed population of reading and playing devices. Given the extremely rapid technological evolution of reading and playing devices it is impossible to conclusively establish any definitive link between measured and actual performance, especially for marginal discs.

The DVD Forum has established numerous verification laboratories around the world charged with determining and certifying the conformance of the various types of DVD discs and devices to their respective specifications. Philips Electronics, Ricoh and Sony deal with DVD+R and DVD+RW. While these labs are considered to be the last word in verifying disc conformance to specifications and quality testing they are unable to provide any guidance regarding the reading or writing performance of discs with the already installed population of recorders, drives or players. This is one of the many functions served by several ad hoc industry groups such as the DVD+RW Compatibility and Convergence Group (DCCG), Recordable DVD Council (RDVDC), RW Products Promotion Initiative (RWPPI) and the Optical Storage Technology Association (OSTA).

When assessing disc quality keep in mind the huge number of variables involved. These include such things as discs with their different types, batches and manufacturers, recording software and hardware in their many varieties and versions, diverse recording conditions encountered, different test equipment employed, operators of differing experience and even by the physical handling of the discs themselves. Consequently, judgments should be made on a relative rather than absolute basis.

DISC CONSTRUCTION AND MANUFACTURING

What is the construction of DVD-R and DVD+R discs?

DVD-R and DVD+R discs can be either single or double-sided. A single-sided (SS) disc is composed of a recording side and a dummy side while a double-sided (DS) disc consists of two recording sides. The recording side of a DVD-R and DVD+R disc is a sandwich of a number of layers. First comes a polycarbonate plastic substrate containing a shallow spiral groove extending from the inside to the outside diameter of the disc. A DVD-R disc additionally includes pits and lands on the areas between the coils of the groove (land pre-pits). Added to this substrate is an organic dye recording layer (azo, cyanine, dipyrromethene or others) followed by a metal reflective layer (silver, silver alloy, gold). The dummy side of a single-sided disc consists of an additional flat polycarbonate plastic substrate (sometimes with an additional metal layer to obscure the bonding layer from view for aesthetic purposes). An adhesive then bonds two recording sides (for a double-sided) or a recording and dummy side (for a single-sided) together into the final disc. Some single-sided discs are also topped on the dummy side with decorations or additional layers that provide surfaces suitable for labeling by inkjet, thermal transfer or re-transfer printers.

How are DVD-R and DVD+R discs made?

The first step in manufacturing a DVD-R or DVD+R disc is to fabricate the polycarbonate plastic substrates (incorporating the spiral groove and land pre-pits) using an injection molding process. The dye is then applied using spin coating and the metal layers by means of DC sputtering. After both sides of the disc are completed they are bonded together using a hot melt, UV cationic or free radical process. Additional decoration or printable layers are typically applied using screen printing methods. A DVD-R (General) disc undergoes a further manufacturing step in which a specialized computer DVD recorder is used to “prewrite” information in the Control Data Zone of its Lead-in Area to inhibit direct copying of prerecorded DVD-Video discs encrypted with the Content Scrambling System (CSS). Apart from this, and some minor differences in the configuration of the molding stamper used to create the substrates, the process for manufacturing DVD-R and DVD+R discs is virtually identical.

What is the construction of DVD-RW, DVD+RW and DVD-RAM discs?

To allow information to not only be written but also re-written many times over, DVD-RW, DVD+RW and DVD-RAM (rewritable) disc construction is more complex than that of DVD-R and DVD+R (recordable). Just like a recordable disc, a rewritable disc can be either single or double-sided. The recording side of a rewritable disc also uses multiple layers beginning with a polycarbonate plastic substrate containing a shallow spiral groove extending from the inside to the outside diameter of the disc. A DVD-RW disc

additionally includes pits and lands on the areas between the coils of the groove (land pre-pits) and a DVD-RAM disc also inside the groove itself (land and groove). Next comes a dielectric layer (zinc sulfide and silicon dioxide), followed by a phase-change alloy recording layer (either indium, silver, tellurium and antimony or germanium, tellurium and antimony), another dielectric layer and a metal reflective layer (silver, silver alloy, aluminum). Additional layers may also be incorporated above or below the dielectric layers (germanium nitride, silicon carbide, silicon dioxide, silicon nitride, zinc sulfide, antimony telluride and others). The dummy side consists of a flat polycarbonate plastic substrate sometimes with an additional metal layer. An adhesive then bonds the sides together into a single disc. The exterior of the recording side may also be “hard coated” with a transparent material (indium tin oxide, silicon-based lacquer and others) designed to repel dust and resist fingerprints and scratches. Similar to a barcode in appearance, a DVD-RAM or DVD-RW disc can also contain near its inner diameter an optional Burst Cutting Area (BCA) or Narrow Burst Cutting Area (NBCA) to supply information required to implement Content Protection for Recordable Media (CPRM).

How are DVD-RW, DVD+RW and DVD-RAM discs made?

As with DVD-R and DVD+R, producing DVD-RW, DVD+RW or DVD-RAM discs involves using multiple manufacturing stages. The first step is to fabricate the substrates (incorporating the spiral groove, land pre-pits and embossed areas) by injection molding. The dielectric layers, phase-change recording, reflective and any additional layers are applied to the substrate using DC, RF and reactive sputtering. After both sides of the disc are completed they are bonded together using a hot melt, UV cationic or free radical process. Since the sputtering process lays down the phase-change alloy in its amorphous condition a special device using powerful lasers (initializer) returns the recording layer back to its crystalline state. Subsequent recording then results in less reflective (dark) areas being written against a more reflective (bright) background. The Burst Cutting Area (BCA) or Narrow Burst Cutting Area (NBCA) is marked into the disc using the initializer or a dedicated device outfitted with a YAG (yttrium aluminum garnet) laser. Hard coating can be applied to the substrates at different stages in disc manufacturing using a variety of processes such as spin coating, vacuum deposition and screen printing. A DVD-RAM disc can optionally undergo a further manufacturing step in which it is physically formatted by a conventional computer recorder (to detect and map any defective sectors). Apart from some minor differences in the configuration of the molding stamper used to create the substrates the process for manufacturing DVD-RW and DVD+RW discs is virtually identical while DVD-RAM fabrication is more involved.

How does writable DVD and CD disc manufacturing differ?

Apart from the thinner substrates and tighter manufacturing tolerances, the most significant difference between writable DVD and CD manufacturing is the need to perfectly bond two DVD halves together to create a disc that is the same thickness as a CD (1.2 mm). It is imperative that the two disc halves have the same long-term mechanical behavior to ensure that the resulting disc maintains its thermo-mechanical stability. This is particularly important for high-speed discs where flatness and uniformity are paramount. Writable DVD disc manufacturing equipment and production steps (with the addition of the bonding stage) closely resemble those used to fabricate their CD counterparts. In fact, many media manufacturers have simply modified their existing CD-R and CD-RW equipment to produce writable DVD discs although it is generally expected to become less feasible to do so (for productivity and product quality demands) as the technology and business evolves.

APPENDIX A — SUGGESTED FURTHER READING AND RESOURCES

BOOKS

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STUDIES

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MAGAZINES AND NEWSLETTERS

AV Video Multimedia Producer
Camcorder & ComputerVideo
Computer Technology Review
Computer Video
DV Magazine
EMedia, the Digital Studio Magazine
Film & Video
Government Video
Medialine
Mediaware
Millimeter
One to One
Optical Disc Systems
TapeDisc Business
Videomaker Magazine
Video Systems

www.avvideo.com
www.candcv.com
www.wwpi.com
www.computervideo.net
www.dv.com
www.emedialive.com
www.filmandvideomagazine.com
www.governmentvideo.com
www.medialinenews.com
www.recordingmedia.org
www.millimeter.com
www.oto-online.com
www.opticaldisc-systems.com
www.tapedisc.com
www.videomaker.com
www.videosystems.com

DIRECTORIES AND BUYER'S GUIDES

Billboard International Buyer's Guide
DVD Directory
EMedia, the Digital Studio Magazine Buyer's Guide
Gold Book
International DVD and CD Plant Directory
Production Services Buyers Guide

www.billboard.com
www.newmediainfo.com
www.emedialive.com
www.oto-online.com
www.oto-online.com
www.newmediainfo.com

EXHIBITIONS, TRADE SHOWS AND CONFERENCES

AES
CEATEC Japan
CeBIT
COMDEX
DS Expo: Data Storage Expo & Conference Tokyo
DV Expo
DVD Entertainment Conference & Showcase
DVD Europe
DVD International Conference & Exhibition
Government Video Technology Expo
IFA
International Consumer Electronics Show
LA DV Show
Macworld Conference & Expo
Media-Tech Expo
NAB
Optical Storage Symposium (OSS)
Replication Asia
Replication Expo

www.aes.org
www.ceatec.com
www.cebit.de
www.comdex.com
www.reedexpo.co.jp
www.dvexpo.com
www.recordingmedia.org
www.dvdeurope2004.com
www.itl.nist.gov
www.gvexpo.com
www.ifa-berlin.de
www.cesweb.org
www.ladvshow.com
www.macworldexpo.com
www.media-tech.net
www.nab.org
www.osta.org
www.replicationasia.com
www.howellexpo.com

GENERAL INFORMATION WEB SITES

CD Freaks	www.cdfreaks.com
CDR-Info	www.cdrinfo.com
CDRLabs	www.cdrlabs.com
CD-RW Central	www.cdrwcentral.com
cd-rw.org	www.cd-rw.org
Dvdoctor	www.dvdoctor.net
DVD FAQ	www.dvddemystified.com
DVDplusRW.org	www.dvdplusrw.org
DVD-Recordable.org	www.dvd-recordable.org
DVDRhelp	www.dvdrhelp.com
Mpeg.org	www.mpeg.org
Optical Storage Technology Association (OSTA)	www.osta.org

GENERAL INFORMATION NEWSGROUPS AND LISTS

alt.dvd.video
alt.video.dvd
alt.video.dvdr
rec.video.dvd
rec.video.desktop
www.tully.com/dvdlist
<http://lists.apple.com/mailman/listinfo/dvdlist>

INDUSTRY ASSOCIATIONS AND ORGANIZATIONS

CDs21 Solutions (CDs21)	www.cds21solutions.org
Consumer Electronics Association (CEA)	www.ce.org
Copy Protection Technical Working Group (CPTWG)	www.cptwg.org
DVD Application Group	www.dvdapplicationgroup.com
DVD Association (DVDA)	www.dvda.org
DVD Forum	www.dvdforum.com
DVD+RW Alliance	www.dvdrw.com
Industrial Technology Research Institute (ITRI)	www.itri.org.tw
International Disc Duplicating Association (IDDA)	www.discdupe.org
International Federation of the Phonographic Industry (IFPI)	www.ifpi.org
International Optical Disc Replicators Association (iODRA)	www.iodra.com
International Recording Media Association (IRMA)	www.recordingmedia.org
Japan Recording Media Industries Association	www.jria.org
Optical Storage Technology Association (OSTA)	www.osta.org
Recordable DVD Council (RDVDC)	www.rdvdc.org
RAM Promotion Group (RAMPRG)	www.ramprg.com
RW Products Promotion Initiative (RWPPPI)	www.rwppi.com
SCSI Trade Association	www.scsita.org
Serial ATA Working Group	www.serialata.org
Society of Motion Picture and Television Engineers	www.smpte.org
1394 Trade Association	www.1394ta.org
USB Implementers Forum	www.usb.org

LICENSING, SPECIFICATIONS AND STANDARDS ORGANIZATIONS

American National Standards Institute (ANSI)	www.ansi.org
Dolby Laboratories	www.dolby.com
Discovision Associates (DVA)	www.discovision.com
DVD 6C Licensing Agency	www.dvd6cla.com
DVD Copy Control Association (DVD CCA)	www.dvdcca.org
DVD Format Logo Licensing Corporation (DVD FLLC)	www.dvdfllc.co.jp
ECMA International	www.ecma-international.org
4C Entity	www.4centity.com
International Committee for Information Technology Standards	www.incits.org
International Electrotechnical Commission (IEC)	www.iec.ch
International Organization for Standardization (ISO)	www.iso.org
Macrovision Corporation	www.macrovision.com
MPEG LA, LLC.	www.mpegla.com
Optical Storage Technology Association (OSTA)	www.osta.org
Philips Intellectual Property & Standards	www.licensing.philips.com
Small Form Factor Committee (SFFC)	www.sffcommittee.org
Verance Corporation	www.verance.com

APPENDIX B — INDUSTRY AND PRODUCT CONTACTS

MARKET RESEARCH AND CONSULTING FIRMS

Cahners In-Stat Group	www.instat.com
Forget Me Not Information Systems Inc.	73144.1631@compuserve.com
Gartner, Inc.	www.gartner.com
IDC	www.idcresearch.com
InfoTech, Incorporation	www.infotechresearch.com
Jon Peddie Research	www.jonpeddie.com
Magnetic Media Information Services (MMIS)	www.mmislueck.com
Santa Clara Consulting Group	www.sccg.com
Strategic Marketing Decisions (SMD)	www.smdcorp.com
Techno Systems Research Co., Ltd. (TSR)	www.t-s-r.co.jp
Understanding and Solutions	www.uands.com

DUPLICATION AND PUBLISHING SYSTEMS

ACARD Technology Corp.	www.acard.com
Alea Systems, Inc.	www.alea.com
Alera Technologies, LLC.	www.aleratec.com
An Chen Computer Co. Ltd.	www.copystar.com.tw
CopyPro, Inc.	www.copypro.com
Copytrax Technologies	www.copytrax.com
Cyclone USA	www.cdcyclone.com
Discmatic	www.discmatic.com
DixxPli USA	www.dixxpli.com
Hoei Sangyo Co., Ltd.	www.hoei.co.jp
ILY Enterprise Inc.	www.ily.com
Imedia Technologies (IMT)	www.imt-sa.com
Interactive Media Corporation	www.interactivemediacorp.com
JukeBox Information Systems	www.jbis.com
LSK Data Systems GmbH	www.lskdata.de
Luminex Software, Inc.	www.luminex.com
Mediatechnics Systems	www.mediatechnics.com
MF Digital	www.mfdigital.com
Microboards Technology	www.microboards.com
Microsynergy	www.idt-microsynergy.com
Microtech Systems	www.microtech.com
Niscoa, Inc.	www.niscoa.com
Nistec Corporation	www.nistec.co.jp
Odixion	www.odixion.com
OptoMedia Storage Solutions Limited	www.optomedia.co.uk
Orient Instrument Computer Co., Ltd.	www.orient-computer.co.jp
Otari, Inc.	www.otari.com
Pengo Technologies	www.pengo.com
Primera Technology, Inc.	www.primera.com
Rimage Corporation	www.rimage.com
Rimax International Ltd.	www.rimax.net
R-Quest Technologics, LLC	www.r-quest.com
Terra Computer Systems	www.terra.cz
The Logical Company	www.u-master.com

T.S. Solutions
Telex Communications, Inc.
Verity Systems
Young Minds, Inc.
Wytron Technology Co. Ltd.

www.ts-solutions.com
www.telex.com
www.veritysystems.com
www.ymi.com
www.wytron.com.tw

DISC LABELS AND PRINTERS

Avery Dennison Corporation
Burlington Paper
Casio Computer Co., Ltd.
CopyPro, Inc.
Epson America, Inc.
Fellowes/Neato
Imation Corp.
Intenso GmbH
Kyso Inc.
LSK Data Systems GmbH
Memorex Products, Inc.
MicroVision Development, Inc.
MF Digital
Primera Technology
Rimage Corporation
TDK Electronics Corp.
Verbatim Corporation
Verity Systems

www.avery.com
www.burlingtonpaper.com
www.casio.com
www.copypro.com
www.epson.com
www.fellowes.com
www.imation.com
www.intenso.de
www.kyso.com
www.lskdata.de
www.memorex.com
www.surething.com
www.mfdigital.com
www.primeratechnology.com
www.rimage.com
www.tdk.com
www.verbatim.com
www.veritysystems.com

DISC MANUFACTURERS/BRANDS

Advanced Optical Disc Holland B.V.
Alera Technologies, LLC.
BeAll Developers, Inc.
CMC Magnetics Corp.
Daxon Technology Inc.
Digital Data Technologies Sdn Bhd
Digital Disc Dessau GmbH
Emtec-Multimedia Inc.
Euro Digital Disc Productions GmbH
Fuji Photo Film
Gigastorage Corporation
Imation Corp.
Infodisc Technology
Info Smart Technology Limited
Intenso GmbH
Inter Media Co., Ltd.
JVC Company of America
Khypermedia Corporation
KMP Inc.
Lead Data Inc.
MAM-A Inc.
Manufacturing Advanced Media Europe (MAM-E)
Maxell Corporation
MDA Technology Limited

www.aodgroup.com
www.aleratec.com
www.bealldev.com
www.cmcdisc.com
www.daxontech.com
www.ddt.com.my
www.digital-disc.de
www.datastoremedia.com
www.euro-digital-disc.de
www.fujifilm.com
www.gigastorage.com
www.imation.com
www.infodisc.com.tw
www.infosmart.com.hk
www.intenso.de
www.intermedia.jp
www.jvc.com
www.khypermediaco.com
www.kmpmedia.com
www.leaddata.com.tw
www.mam-a.com
www.mam-e.com
www.maxell.com
www.mda.com.hk

Megan Media Holdings
Memorex Products, Inc.
MJC Singapore Pte Ltd.
Moser Baer India Ltd. (MBI)
Moulage Plastique de L'Ouest (MPO)
Nashua Media Products
Piodata Inc.
PrimeDisc Technologies GmbH
Prodisc Technology Inc.
Optodisc Technology Corporation
Pengo Technologies
Philips Electronics
Quantegy, Inc.
Ricoh Corporation
Ritek Corporation
Sentinel N.V.
Sony Electronics Inc.
Taiyo Yuden Co. Ltd.
Traxdata/Conrexx Technology B.V.
TDK Electronics Corp.
UI Tran Technology & Service Co.
UmeDisc Ltd.
Verbatim Corporation
Wing Shing Optical Disc Co. Ltd.

www.meganmedia.com.my
www.memorex.com
www.mjc.com.sg
www.moserbaer.net
www.hi-space.com
www.nashuamedia.com
www.piodata.com
www.primedisc.com
www.prodisc.com.tw
www.optodisc.com
www.pengo.com
www.philips.com
www.quantegy.com
www.ricoh.co.jp
www.ritek.com.tw
www.sentinel.be
www.mediabysony.com
www.t-yuden.com
www.traxdata.com
www.tdk.com
www.ultran.com.tw
www.umedisc.com
www.verbatim.com
www.wing-shing.com

RECORDER MANUFACTURERS/BRANDS

Accesstek Inc.
Actima Technology Corporation
Alera Technologies, LLC.
AOpen Inc.
ASUSTek Computer Inc.
Behavior Tech Computer Corp.
BenQ Corporation
BUSlink USA Inc.
CIS Technology, Inc.
Digital Research Technologies
Fantom Drives
Hewlett-Packard Company
I/O Magic Corporation
Iomega Corporation
Kanguru Solutions
Khypermedia Corporation
LaCie
LG Electronics Inc.
Lite-On IT
Matsushita Electric Industrial Co. Ltd./Panasonic
Memorex Products, Inc.
Micro Solutions Inc.
Mitsumi Electric Co., Ltd.
NEC Corporation
Norcent Technology Inc.
Nu Technology Inc.
OptoRite

www.accesstek.com.tw
www.actima.com.tw
www.aleratec.com
www.aopen.com
www.asus.com
www.btc.com.tw
www.benq.com
www.buslink.com
www.cis.com.tw
www.dr-tech.com
www.fantomdrives.com
www.hp.com
www.iomagic.com
www.iomega.com
www.kanguru.com
www.khypermediaco.com
www.lacie.com
www.lge.com
www.liteonit.com
www.panasonic.com
www.memorex.com
www.micro-solutions.com
www.mitsumi.com
www.nec.co.jp
www.norcent.com
www.nu-global.com
www.optorite.com

Pacific Digital
Philips Electronics
Pine Technology
Pioneer Corporation
Plextor Corp.
Ricoh Company
Sanyo Electric Co., Ltd.
Sony Corporation
TDK Electronics Corp.
Teac Corporation
Toshiba

www.pacificdigitalcorp.com
www.philips.com
www.pinegroup.com
www.pioneerelectronics.com
www.plextor.com
www.ricoh.co.jp
www.burn-proof.com
www.sony.com
www.tdk.com
www.teac.com
www.toshiba.com

DVD-VIDEO RECORDERS AND CAMCORDERS

Afreey Inc.
Apex Digital Inc.
CyberHome Entertainment, Inc.
Daewoo Electronics
Daytek Electronics Corp.
Ellion Digital
Gateway, Inc.
Hitachi, Ltd.
Lite-On IT
Magnavox Consumer Electronics
Matsushita Electric Corporation/Panasonic
Mico Electric Ltd.
Mustek, Inc.
Philips Electronics N.V.
Pioneer Corporation
Polaroid (The Petters Group, LLC)
Sampo Corporation
Samsung
Samwin Hong Kong Limited
Sharp Electronics Corp.
Sony Electronics
Tae-Young Telstar Co. Ltd.
Thomson/RCA
Toshiba Corporation
Victor Company of Japan/JVC
Yamaha Corporation
Zenith Electronics Corporation

www.afreey.com.tw
www.apexdigitalinc.com
www.cyberhome.com
www.e-daewoo.com
www.daytek.ca
www.elliondigital.com
www.gateway.com
www.hitachi.com
www.liteonit.com
www.magnavox.com
www.panasonic.com
www.micoelectric.com
www.mustek.com
www.dvdrecorder.philips.com
www.pioneerelectronics.com
www.polaroidelectronics.com
www.sampo.com.tw
www.samsung.com
www.samwin.com.hk
www.sharp-usa.com
www.sony.com
www.tytelstar.com
www.rca.com
www.toshiba.com
www.jvc.com
www.yamaha.com
www.zenith.com

DVD-VIDEO AUTHORIZING AND ENCODING

Adaptec, Inc.
Adobe Systems Inc.
ADS Technologies
Ahead Software
Apple Computer, Inc.
AVerMedia Inc.
Canopus Corporation
Custom Technology Corporation
CyberLink Corp.

www.adaptec.com
www.adobe.com
www.adstech.com
www.nero.com
www.apple.com
www.aver.com
www.canopus.com
www.cinemacraft.com
www.gocyberlink.com

Darim Vision Co., Ltd.
Dazzle Multimedia
Digigami, Inc.
Digital Ventures Diversified
DV Studio Technologies, LLC
Globalstor Data Corporation
Heuris Logic Inc.
InterVideo, Inc.
Ligos Corporation
Margi Systems
Magix
Matrox Electronic Systems Ltd.
Mediostream, Inc.
Nanocosmos GmbH
NewSoft Inc.
Optibase, Inc.
Pinnacle Systems, Inc.
PixelTools Corporation
Plextor Corp.
Roxio, Inc.
Sonic Foundry, Inc.
Sonic Solutions
Sony BSSC
321 Studios
Ulead Systems, Inc.
Vitec Multimedia
Wired Inc.
Zapex Technologies, Inc.

www.darim.com
www.dazzle.com
www.digigami.com
www.dvdcomposer.com
www.dv-studio.com
www.globalstor.com
www.heuris.com
www.intervideo.com
www.ligos.com
www.margi.com
www.magix.com
www.matrox.com
www.mediostream.com
www.nanocosmos.de
www.newsoftinc.com
www.optibase.com
www.pinnaclesys.com
www.pixeltools.com
www.plextor.com
www.roxio.com
www.sonicfoundry.com
www.sonic.com
bssc.sel.sony.com
www.321studios.com
www.ulead.com
www.vitecmm.com
www.wiredinc.com
www.zapex.com

DVD-AUDIO AUTHORIZING AND ENCODING

Cube Technologies GmbH
Minnetonka Audio Software, Inc.
SADiE
Sonic Solutions

www.cube-tec.com
www.minnetonkaaudio.com
www.sadie.com
www.sonic.com

RECORDING SOFTWARE

Ahead Software
Aplix Corporation
B.H.A. Software Corporation
Charismac Engineering
Gear Software
Golden Hawk Technology
NewTech Infosystems
Padus, Inc.
Pinnacle Systems, Inc.
PoINT Software and Systems
Roxio, Inc.
Software Architects, Inc.
Sonic Solutions
ValuSoft

www.nero.com
www.aplix.co.jp
www.bhacorp.com
www.charismac.com
www.gear.com
www.goldenhawk.com
www.ntius.com
www.padus.com
www.pinnaclesys.com
www.pointsoft.de
www.roxio.com
www.softarch.com
www.sonic.com
www.valusoft.com

JUKEBOXES AND NETWORK STORAGE

ASACA Corporation
ASM GmbH & Co. KG
DAX Archiving Solutions
DISC, Inc.
JVC Professional Products Company
Kubik Enterprises Inc.
Luminex Software, Inc.
Pioneer Corporation
Plasmon
PowerFile, Inc.
Procom Technology, Inc.
QStar Technologies

www.asaca.com
www.asm-jukebox.de
www.smartdax.com
www.disc-storage.com
pro.jvc.com
www.kubikjukebox.com
www.luminex.com
www.pioneerelectronics.com
www.plasmon.com
www.powerfile.com
www.procom.com
www.qstar.com

DISC AND DRIVE QUALITY ANALYSIS AND TESTING

Adivan High Tech AG
Almedio Inc.
AudioDev
DaTARIUS Technologies GmbH
Dr. Schwab Inspection Technology GmbH
Eclipse Data Technologies
Efocus International Ltd.
Expert Magnetics Corp.
Intellikey Labs
Kenwood TMI Corporation
Katano Matsushita Co., Ltd.
Philips Intellectual Property & Standards
Pioneer Corporation R&D
Professional Multimedia Test Centre
Pulstec Industrial Co., Ltd.
Quantized Systems
Sony Precision Technology, Inc
Teac Corporation
Testronic Laboratories
Victor Company of Japan, Ltd.

www.adivan.com
www.almedio.co.jp
www.audiodev.com
www.datarius.com
www.schwabinspection.com
www.eclipsedata.com
www.efocus.co.uk
www.expertmg.co.jp
www.intellikeylabs.com
www.kenwoodtmi.co.jp
www.panasonic.co.jp/kmc
www.licensing.philips.com
www.pioneer.co.jp
www.pmtctest.com
www.pulstec.co.jp
www.quantized.com
www.sonypt.com
www.teac.co.jp
www.testroniclaboratories.com
www.jvc-victor.co.jp

DISC REPAIR, RESTORATION AND DATA RECOVERY

Action Front Data Recovery Labs, Inc.
Acodisc
Alera Technologies, LLC.
ArrowKey, Inc.
AuralTech
CD Data Guys
Compact Disc Repairman, Inc.
Digital Innovations
Doctor Disc Company
ESS Data Recovery
Ontrack Data International
Skippy Disc

www.actionfront.com
www.acodisc.com
www.aleratec.com
www.cdrom-prod.com
www.auraltech.com
www.cddataguys.com
www.cdrepairman.com
www.digitalinnovations.com
www.drdiscoompany.com
www.savemyfiles.com
www.ontrack.com
www.skippydisc.com

DISC DESTRUCTION AND RECLYCLING

Alera Technologies, LLC.	www.aleratec.com
CD ROM Incorporated	www.cdrominc.com
Ecodisk	www.ecodisk.com
EcoMedia	www.ecomedia.com
Fellowes, Inc.	www.fellowes.com
GBC ModiCorp Limited	www.gbcmodi.com
Geo-Tech Polymers	www.geo-tech.com
Greendisk	www.greendisk.com
Hammacher Schlemmer and Company	www.hammacher.com
Hetzel Elektronik-Recycling GmbH	www.her-online.de
Intimus Business Systems	www.intimus.com
Lacerta Group, Inc.	www.lacerta.com
MBA Polymers, Inc.	www.mbapolymers.com
MRC Polymers	www.mrcpolmers.com
Niscoa, Inc.	www.niscoa.com
Olympia Business Systems, Inc.	www.olympia.to
Security Engineered Machinery	www.semshred.com
Sony Disc Manufacturing	www.sdm.sony.com

ABOUT OSTA

The Optical Storage Technology Association (OSTA) was incorporated as an international trade association in 1992 to promote the use of writable optical technologies and products. The organization's membership includes manufacturers and resellers from three continents, representing more than 85 percent of worldwide writable optical product shipments, working together to educate consumers and shape the future of the optical storage industry. Included among OSTA's many accomplishments are its groundbreaking CD-R and recordable DVD compatibility efforts, development of the Universal Disc Format (UDF) as well as the MultiRead, MultiPlay, MultiAudio and MusicPhotoVideo (MPV) specifications.

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