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DVD White Paper

An Introduction to DVD-RW

Overview

The DVD-RW format is a member of the DVD Forum's family of DVD specifications. As its abbreviated name suggests, DVD-RW is a rewritable medium that allows users to record, erase and re-record their own DVD discs more than 1,000 times. Officially known as DVD Re-recordable, DVD-RW can be thought of as a rewritable version of the write-once DVD-Recordable (DVD-R) format. As with DVD-R, the concept of DVD-RW is to provide a user-recordable DVD medium that is physically compatible with existing DVD video players and DVD-ROM drives. DVD-RW discs can contain up to 4.7 billion bytes of information per side, and can be used to store video, audio, and other types of data.

The DVD-RW format was designed to effortlessly merge with the existing DVD environment. For example, DVD-RW discs do not use protective cartridges, allowing them to be used with the disc loading mechanisms in all existing players and drives. The format also specifies a relatively high information surface reflectivity, making it easy for standard playback optics to recognize and play recorded discs. From a manufacturing point of view, DVD-RW media are assembled using a four-layer process very similar to the one used to make CD-RW media (see figure one). This allows existing disc manufacturing lines to be used for DVD-RW production without extensive retooling.

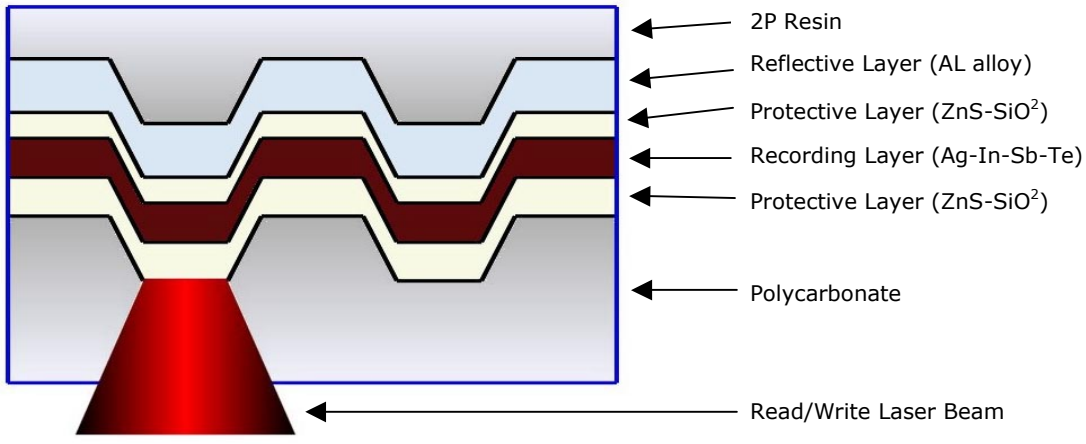

Figure One: DVD-RW Disc Construction

Recording Mechanism

DVD-RW discs use phase change technology for reading, writing, and erasing information. A 650 nanometer wavelength laser beam heats a phase change alloy to change it between either crystalline (reflective) or amorphous (dark, non-reflective) conditions, depending on the temperature level and subsequent rate of cooling. The resulting difference between the recorded dark spots and erased, reflective areas between the spots is how a player or drive can discern and reproduce stored information (see figure two).

There are two distinct laser power levels used for erasing and writing. The highest power level causes the surface to become less reflective in the area where the laser is turned on, which is how information is written to the phase change recording layer. Before reaching the writing power level, however, a lower, intermediate power level is first applied to erase previously recorded dark spots by returning them to a uniformly "blank" (reflective) condition. Since the intermediate erase power must first be reached before the writing power, direct overwriting (DOW) can be achieved – a significant advantage of phase change technology.

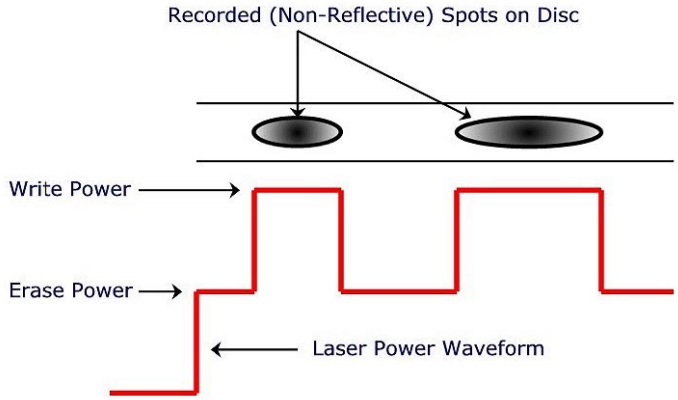

Figure Two: Phase Change Recording Mechanism (Conceptual)

Note that the diagram in figure three illustrates that the recording laser is modulated by a series of short pulses rather than simply following the input signal's "on" pulses. This allows a recorder to precisely control the size and shape of the recorded dark spots by controlling the effects of latent surface heating. A single, continuous pulse might otherwise cause melting to continue for a short while even after the laser is turned off, causing a distortion of the written dark spot's shape. This multiple-pulse waveform represents the *write strategy* used for a given disc, and can be modified by the recording drive as required to achieve the best quality signal. Phase change recording layer formulations in DVD-RW media use silver, indium, antimony and tellurium, similar to the alloy used in CD-RW media; differing alloy combinations used by various manufacturers can require write strategy adjustments.

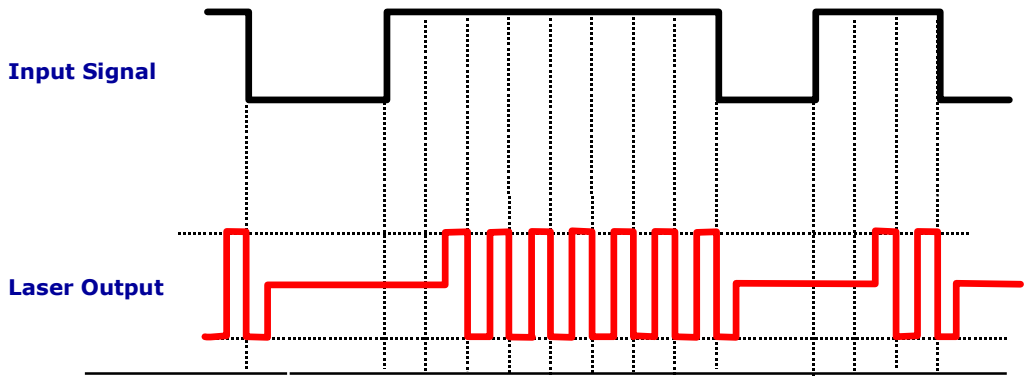

Figure Three: Input Data Signal vs. Laser Writing Signal

Compatibility

Phase change technology can achieve relatively high disc reflectivity ratios, making it suitable for use with traditional player optic designs. The DVD-RW specification requires a reflectivity ratio of 18% to 30%, which is precisely the same range that is specified for the top layer in a replicated dual-layer DVD-ROM (read only) disc. Since every DVD video player and DVD-ROM drive is required to play dual-layer replicated discs, DVD-RW media can theoretically be played by all players and drives as well. This capability is at the heart of what the DVD-RW format's designers wanted to achieve: a fully compatible rewritable DVD format.

Practically speaking, however, there are some exceptions to achieving full compatibility with existing players. First, some players mistakenly assume that DVD-RW discs are indeed dual layer discs, and attempt in vain to locate a non-existent second layer. This can result in some players or ROM drives refusing to play DVD-RW discs. The problem can be easily resolved with a minor change to a player or drive's internal control software (firmware).

Some players determine what type of disc is being played by reading a media identification code present on all types of DVD media. Since DVD-RW is a new format, some players and drives may not recognize the disc type and refuse to play them. Again, this problem is correctable with a minor firmware modification.

Finally, the initial version 1.0 DVD-RW media (released only in Japan in late 1999) includes a pre-obscured or embossed area of each disc to ensure that decryption keys used to protect motion picture content cannot be recorded. This embossed area is unreadable by nearly all video players and ROM drives. The next version of DVD-RW, version 1.1, will include a *readable* embossed area so that playback compatibility can be maximized while still protecting against unauthorized recording.

Rewritability Characteristics

DVD-RW media can support more than 1,000 rewrite cycles without signal degradation. This results in a usable life that is superior to magnetic tape, making the format highly suitable for consumer and professional recording applications. Beyond 1,000 cycles, the phase change recording mechanism begins to lose its efficiency, and the recorded signal can approach or exceed the maximum allowable jitter specification allowed by the DVD format (see figure below). Excessive jitter can result in a player or ROM drive having difficulty decoding a recorded signal.

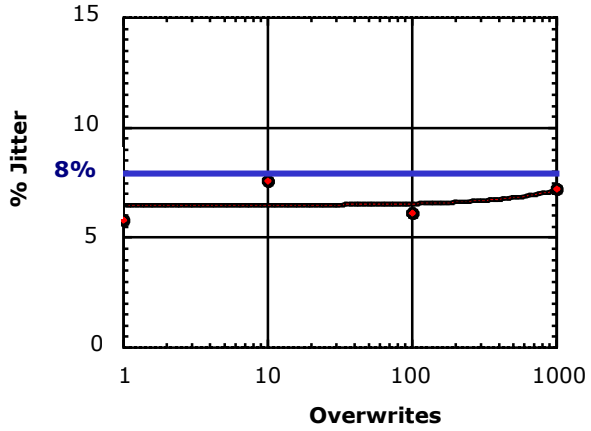

Figure Three: Overwrites vs. % Jitter

Physical Layers vs. Application Layers

All writable DVD formats include a set of specifications that define the media's physical traits and characteristics. This allows any recording or playback device to recognize and write/read data to and from the media. This layer of functionality is the media's *physical layer*. A player or drive's ability to play a recorded DVD-RW disc first depends on its ability to support the DVD-RW physical layer, regardless of what type of data is stored on it.

Once a disc is successfully up and running in a player, drive or recorder, the content or data can be read or written. There are two operational environments where this takes place: standalone "set top" video players and recorders, and computer peripherals such as DVD-ROM drives and DVD writers.

Standalone set top DVD players and recorders must use *application layers* that are defined by the DVD Forum. For example, DVD video players operate with content that has been formatted on a sophisticated DVD video authoring system. This means that video, audio and graphics assets are compressed, mixed together and laid out in such a way that any DVD video player can recognize and display them according to a clearly defined set of navigation instructions. Motion pictures are typically released on

replicated ROM media (the physical layer) and authored using the DVD video format (the application layer). The DVD video format is essentially a publishing format, and is therefore intended to be a one-time-only mastering process.

At the same time, DVD video recorders conforming to DVD Forum specifications can use another application layer known as the video recording (VR) format. The VR format was created by the DVD Forum in order to offer functionality that is very similar to videotape recorders. For example, a user may wish to randomly insert a new video segment anywhere on a disc – a simple task on a VCR. If this were attempted using a DVD video application layer, the process could be difficult and time consuming, because a recorder would have to track and repair any unexpected changes in the navigational functions of the disc. The VR format was therefore designed to allow tape-like flexibility while providing new features such as automatic location of available blank areas and a visual "table of contents" of recordings on the disc.

In the computer environment, a system properly configured with a DVD-ROM drive, audio/video decoders, and DVD player emulation software can recognize and reproduce both DVD video and VR application layers stored on DVD-RW media.

Incremental Writing

When using new, previously unrecorded media, information can be written either as a single "start to finish" disc-at-once session or as a series of sequential sessions. If a disc has been previously recorded, new data segments can be randomly inserted anywhere within the recorded boundary, a feature known as *restricted overwriting*. Random access recordings cannot be made in an area of a disc that has not yet been recorded, however; new data can only be added from the point where the last session was stopped (see figure four).

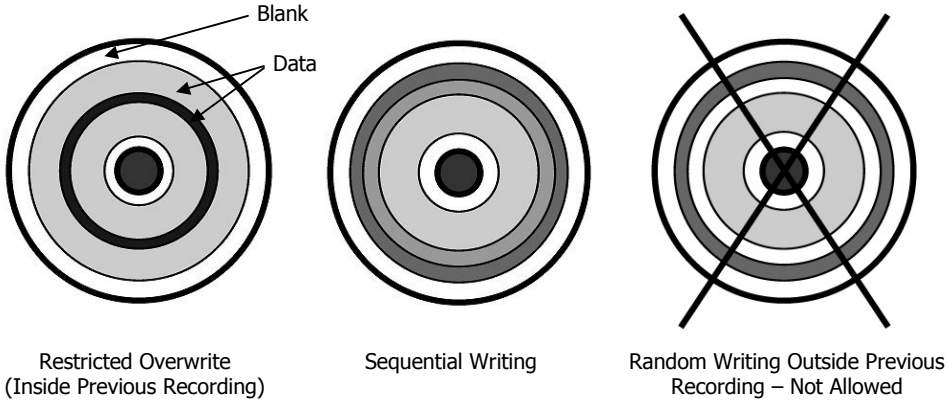

Figure Four: Incremental Writing Examples

Discs recorded incrementally with packet writing are not playable in a DVD-ROM drive until the disc has been finalized with the appropriate file system information and lead-out boundary. They *can* be played prior to finalization by the DVD-RW writer, however.

The second method of incremental writing is through the use of what is known as border zone recording. Border zones allow a very short boundary zone to precede and follow a recording session such that a compatible player or ROM drive will not attempt to play beyond the border into an unrecorded area. This means that a recording can be made on a disc and then accessed on a player or drive before the disc has been completely filled up. Discs with border zones can be operated with DVD-ROM drives or video players which can recognize this method of recording.

Disc Addressing System

DVD-RW media uses the same physical addressing scheme as DVD-R media. During recording, the drive's laser follows a microscopic groove to ensure consistent spacing of data in a spiral track. The walls of the microscopic groove are modulated in a consistent sinusoidal pattern so that a drive can read and compare it to an oscillator for precise rotation of a disc. This modulated pattern is called a *wobble groove*, because the walls of the groove appear to wobble from side to side. This signal is used only during recording, and therefore has no effect on the playback process. Among the DVD family of formats, only recordable media use wobble grooves.

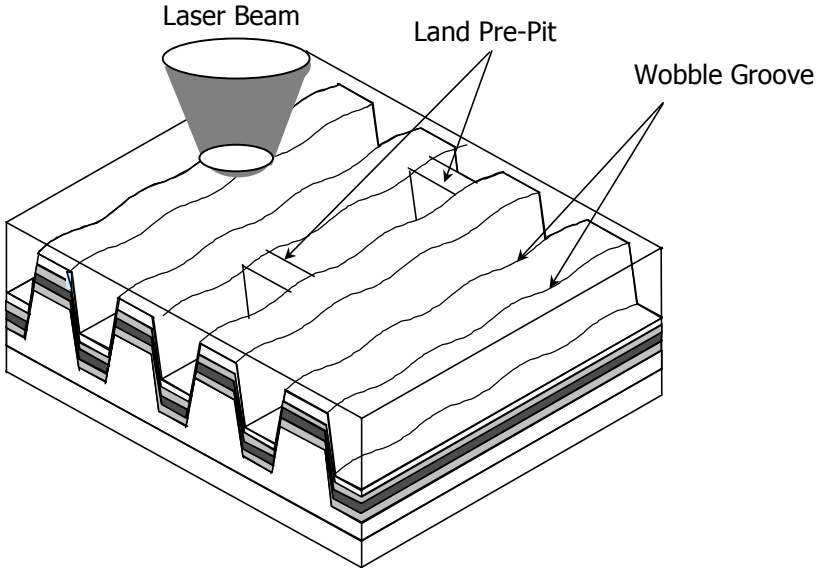

Figure Five: Wobble Groove and Land Pre-Pit Addressing

A pre-formatted addressing scheme, called *land pre-pit*, is used to identify the physical address where data blocks are to be written. This scheme consists of a series of microscopic pits that are embossed in the "land" area between grooves (see figure five).

Content Protection Issues

Content protection takes two forms on DVD-RW media. The first prevents the digital duplication of DVD Video source material that has been encrypted with the Content Scrambling System (CSS). The other prevents unauthorized recording of protected source material while using the video recording (VR) application layer. This second approach is accomplished through the use of Content Protection for Recordable Media (CPRM) on version 1.1 DVD-RW media. If a protected source title permits it, CPRM also provides a supplemental encryption mechanism to allow a single authorized copy to be made of "copy-once" content.

Content protection measures for DVD-RW include:

1. A pre-embossed area of the blank disc to physically prevent the recording of a CSS decryption key. This protects against digital bit-for-bit copies of encrypted titles onto a disc surface. Both versions 1.0 and 1.1 media contains a pre-embossed areas, but the embossing technique used on 1.0 media is unreadable by most video players and ROM drives and thus prevents physical playback compatibility with this version media. Version 1.1 media uses a readable pre-embossed area to allow better playback compatibility.

2. A media identification number, a CPRM component, located in the narrow burst cutting area (NBCA) at the inner radius. The media ID provides a unique serial number for each disc produced by media manufacturers. This can be used along with the media key block (see below) to generate newly encrypted content for titles that allow one copy to be made.

3. If a given program source permits it, CPRM can make one authorized, encrypted copy by using a media key block (MKB) that is embossed on the blank disc. The media key block provides an encryption element that allows a CPRM compliant recorder to re-encrypt video recording format (VR) content. A CPRM compliant, VR compatible player is needed to make use of this newly encrypted data.

Applications

It is technically possible to employ DVD-RW in two key environments: audio/video recording and computer data storage and retrieval. The DVD Forum is discussing use of the format in data applications at the time of this writing.

There are three fundamental advantages of optical disc technology, regardless of format. First is its ability to allow immediate random access to other files or program segments contained on a disc. A program element that might take several minutes to locate on videotape can be found in a few seconds on a DVD disc. Fast random access allows many powerful features such as rapid searches to different chapters and non-linear playback of program elements.

The second key advantage is the lack of physical contact between the disc and playback head, allowing continuous operation without media deterioration. Many commercial and professional applications of video and data storage require frequent retrievals of content, which can result in rapid deterioration of magnetic media. Some public exhibitions, for example, play video segments many times every hour for ten or twelve hours per day. Optical discs provide reliable operation with consistent quality due to the non-contact nature of the playback system.

The third key advantage is removability. Although this is not unique to optical disc technology, the ability to remove and replace discs adds a dimension of usability that captive media such as hard disk drives cannot match. Removable media can be stored offline or in a library system for later use, which effectively allows the recording device to have unlimited capacity. When a disc fills up, a new one can be inserted in seconds. When a hard drive fills up, something must be copied or deleted from it before further recording can be carried out.

DVD-RW media takes full advantage of these capabilities in video applications. Since the Video Recording (VR) application layer was intended to improve on the videotape model, there are many possible applications for DVD-RW wherever videotape is being used. This includes consumer video recording, as well as professional recording, production, editing, and use as a program transmission source.

Conclusion

Today there are many digital storage technologies available, each ostensibly providing the same basic capability of data storage and retrieval. The unprecedented success of the DVD Video format has reinforced the benefit of worldwide standards: the ability to use a storage medium in a variety of playback devices made by many manufacturers.

As with its DVD-R sibling, the DVD-RW format was developed with playback compatibility as its central mission. Pioneer believes that interchangeability between recorders and players is the most important attribute a writable DVD format can offer, because the ability to use content in many places is the essence of a removable storage medium. For this reason, the promise of the DVD-RW format is to be a fundamental enabler in the long-awaited transition from tape to disc.