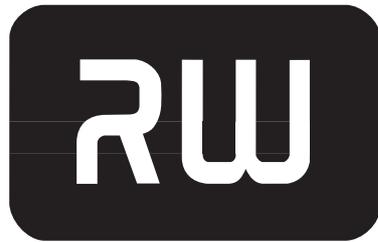


# DVD+ReWritable

## *How it works*



**DVD + ReWritable**

# DVD+ReWritable and how it works

## Introduction

Arising from the need to store ever-larger amounts of data on an optical disc, the pre-recorded DVD-Video (Digital Versatile Disc) can store 4.7 gigabyte of information corresponding to more than two hours of high-quality digital video on a single-sided (CD-size) 12 cm disc. The high-density successor to the popular CD media family, DVD not only meets foreseeable capacity needs, it is also well-suited to the operating needs of the latest multimedia PCs and CE appliances using digitized audio, graphical and video information.

Though pre-recorded DVDs (DVD-ROM and DVD-Video discs) have been around for a while, recordable and rewritable DVDs are a more recent but crucial development. Already, several rewritable formats exist: DVD+RW, DVD-RW and DVD-RAM. Of these, DVD+RW, developed in co-operation by Hewlett-Packard, Mitsubishi Chemical, Philips, Ricoh, Sony and Yamaha, provides a breakthrough in DVD technology: it is the only rewritable format that provides full compatibility with existing DVD-Video players and DVD-ROM drives.

As consumer and IT applications for DVD continue to converge, DVD+RW provides a disc format suitable for both real-time video recording and random data recording – the best of both worlds – in a system that also offers effective means to prevent unauthorized copying of copyright-protected content.

## DVD+RW: Physical format

DVD+RW is designed to be used for both data and video content across PC and entertainment applications. DVD+RW recognizes that these applications are rapidly converging, and that content must be portable across various types of equipment. DVD+RW has therefore been designed to be compatible with existing DVD-ROM and DVD-Video formats.

An important benefit for PC applications is the capability of the DVD+RW format to allow 'CAV recording' (Constant Angular Velocity). Due to the constant rotation speed of the disc CAV recording allows for fast random access. Yet two other benefits are the incorporation of 'Defect management', especially designed for reliability of the data, and 'Quick formatting', enabling instant use of blank discs. Above-mentioned benefits support the use of the format in data systems requiring high performance. For video applications the format has the capability of 'lossless linking' allowing to use variable bit rate recording for longer playing times.

### *DVD+RW at a glance*

<ul style="list-style-type: none"> <li>- Single-sided disc with 4.7 GB capacity</li> <li>- Double-sided disc with 9.4 GB capacity</li> <li>- Uses a bare disc - no cartridge required</li> <li>- 650 nm laser (numerical aperture 0.65)</li> <li>- Constant linear data density</li> <li>- CLV and CAV recording</li> <li>- Write speeds from 1x to 2.4x DVD-Video data rates</li> <li>- Defect management handled by the drive</li> <li>- Quick formatting</li> </ul>	<ul style="list-style-type: none"> <li>- Uses same 8-16 Modulation and RS code as DVD-ROM</li> <li>- Recording                             <ul style="list-style-type: none"> <li>- Sequential and random recording</li> <li>- 32 kB ERCO blocks</li> <li>- Lossless linking</li> </ul> </li> <li>- Address information:                             <ul style="list-style-type: none"> <li>- Spiral groove with radial wobble (32T period)</li> <li>- Phase modulation addresses</li> <li>- Four addresses per ECC block of 32 kB</li> </ul> </li> </ul>
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After recording all physical parameters comply with the DVD-ROM specification.

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## DVD+RW Video format

The pre-recorded DVD-Video market is booming, and Philips believes that DVD-Video will become the mainstream pre-recorded video distribution format. Adding recording capabilities to DVD players will further boost the appeal of the DVD system. Of course, for long-term success it is essential that both home-recorded and pre-recorded discs can be played on the same equipment. This is one reason why DVD+RW is a major breakthrough in rewritable DVD technology.

Philips' DVD+ReWritable Video format, based on the recently announced 4.7 GB DVD+RW storage technology, provides compatibility with existing DVD-Video and DVD-ROM equipment, and allows media interchange between consumer electronic equipment and PC platforms. Moreover, DVD+RW offers the possibility to combine digital video and digital data in a single file system as required for multimedia recording applications.

### *Two-way compatibility*

DVD+RW Video technology provides a unique advantage: Recorded discs can be played back on existing DVD-Video players.

Recordings made with a DVD Video Recorder on DVD+RW discs can be played on DVD Video players as well as on PCs with a DVD-ROM drive and MPEG2 video decoding capability. DVD+RW discs offer up to 4 hours record/playback time per side, resulting in recording capacities of up to 8 hours for double-sided discs.

### *High-quality video at extended recording times*

DVD+RW Video is encoded in MPEG2 with variable bit-rate, providing high bit-rates where necessary while no storage capacity is wasted in scenes with less dynamic video. This means that with the same disc capacity much longer recording times can be achieved, or the recording quality can be further improved without reducing the recording time. DVD-Video playback compatibility with real-time variable bit-rate recording is achieved by using 'Lossless linking', a technique developed specifically for DVD+RW.

### *Simplified editing*

Philips' DVD+RW Video technology also offers easy-to-use editing facilities. Whereas editing private camcorder material on conventional equipment generally requires two video devices, random access to a DVD+RW disc means editing can be done using a single DVD Video Recorder. This brings editing within reach of the average consumer and makes it quick and very easy to use. Because of its PC-compatibility, advanced editing of DVD+RW Video can be done on a PC.

With the addition of DVD+RW to the DVD media family, consumers get the best of both worlds – pre-recorded high-quality recordings, plus home-recording capability. Without doubt, rewritable DVD will stimulate further growth of the DVD Video market, strengthening its long-term interest to both equipment manufacturers and the movie industry alike.

## DVD+ReWritable and how it works

### DVD+RW: PC applications and file handling

With the growing trend towards multimedia documents, which require large amounts of disc space, DVD+RW offers the ability to easily create, share, store and access such content-rich documents using a single disc.

In DVD+RW, data is arranged on a disc according to the industry-standard UDF (Universal Disc Format) standardized and published by OSTA (Optical Storage Technology Association). UDF is well suited to handling file changes and (random) writing of small amounts of data, and facilitates the design of multi-platform applications. Today, UDF is increasingly used for writing to CD-RW discs instead of the less flexible ISO9660 file system format that was developed to handle read-only data applications. Virtually platform-independent, UDF makes DVD systems highly compatible with CD-based data systems. Also, being designed to handle the massive capacities of future optical storage systems, UDF provides excellent forward compatibility.

### DVD+RW: Phase-change technology

In its original state, the recording layer of a DVD+RW disc is polycrystalline. During writing, a focused laser beam selectively heats areas of the phase-change material above the melting temperature (500-700°C), so all the atoms in this area can move rapidly in the liquid state. Then, if cooled sufficiently quickly, the random liquid state is 'frozen-in' and the so-called amorphous state is obtained (see Fig. 1). If the phase-change layer is heated below the melting temperature but above the crystallization temperature (200°C) for a sufficient time (at least longer than the minimum crystallization time), the atoms revert back to an ordered state, i.e. the crystalline state.

The amorphous and crystalline states have different refractive indexes, and can therefore be optically distinguished. In the DVD+RW system, the amorphous state has a lower reflectance than the crystalline state and, during read-out, this produces a signal identical to that of a regular dual layer DVD-ROM disc, making it possible to read DVD+RW discs on DVD-ROM drives and DVD Video players.

The phase-change medium consists of a grooved polycarbonate substrate onto which a stack (usually four layers) is sputtered (see Fig. 2). The phase-change (recording) layer is sandwiched between dielectric layers. A commonly used phase-change material is Ag-In-Sb-Te alloy. The chemical composition of the phase-change layer determines the minimum time of crystallization. The disc structure (layer thickness, thermal capacities and thermal conductivity) determines the cooling rate during writing. Precise control of the recording-layer composition is important to obtain the desired recording properties. In general, low recording powers are achieved by using thin layers. The layer thickness and refractive indexes determine the optical properties of the phase-change medium.

The phase-change medium can be rewritten in a single pass of the focused laser beam; this is sometimes referred to as 'direct overwriting'. In the DVD+RW system, the data is recorded on discs by means of a write strategy, using different laser output levels (see Fig. 3). This strategy (see Fig. 4a) has two parts:

- a pulsed part (pulsing is necessary to write amorphous 'marks'), and
- a non-pulsed part, in which the strategy writes crystalline areas between the marks.

The write strategy therefore writes new data to the disc while simultaneously overwriting old data. Moreover, DVD+RW supports CLV (see Fig. 4a) as well as CAV (see Fig. 4b). This process can be repeated several thousand times.

Figure 1.

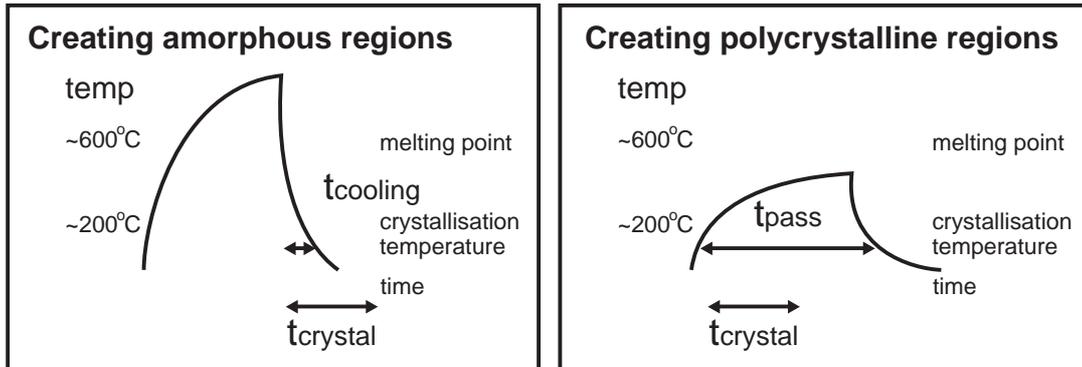


Figure 2.

### Single sided disc (Not to scale)

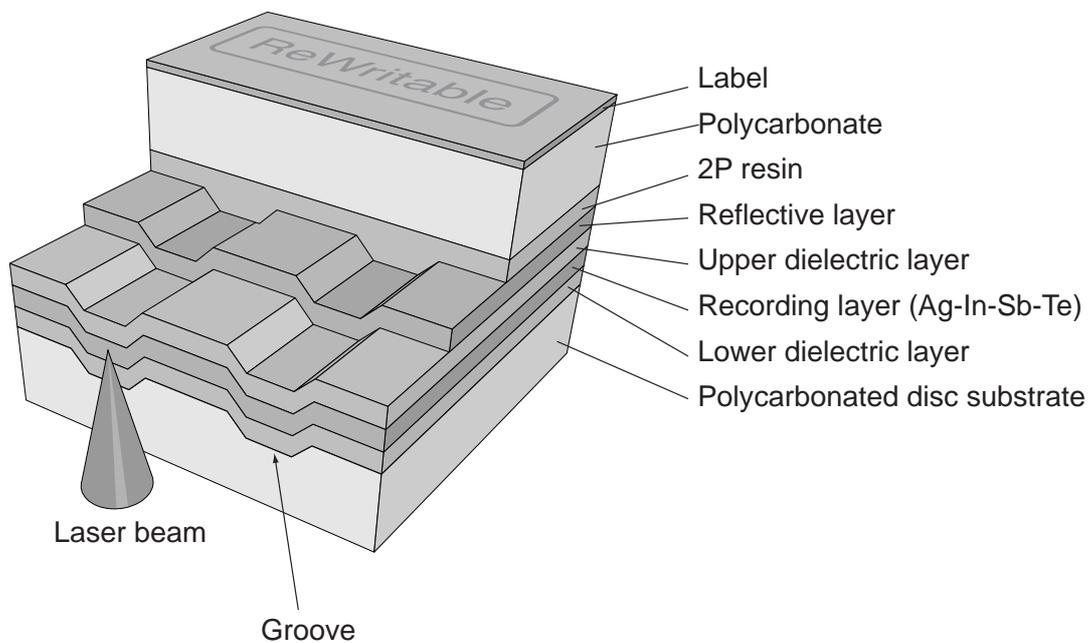


Fig. 2. Section through a single-sided 4-layer DVD+RW disc (4.7 GB).

By exposure to the heat from a laser, the recording layer can be changed from a polycrystalline (more reflective) state to an amorphous (less reflective) state, and vice versa. The layers are deposited onto a polycarbonate substrate; the latter molded with a spiral groove for servo guidance, address information and other data.

DVD+RW discs are supplied ready-for-use in the polycrystalline state. They can be written at between 1x and 2.4x DVD-Video data rates, i.e. 11-26 Mbit/s, allowing CAV operation (Constant Angular Velocity).

# DVD+ReWritable and how it works

Figure 3

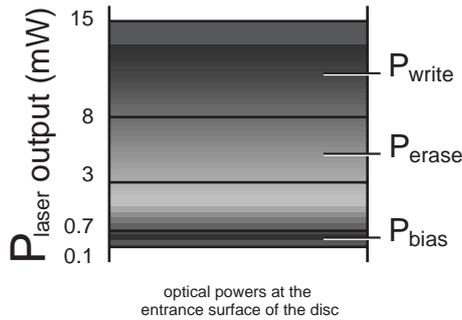


Fig. 3. During recording, the laser output is modulated using three power levels;  $P_{write}$ ,  $P_{erase}$  and  $P_{bias}$ , according to a predefined write strategy. The laser in a DVD+RW system has to be pulsed (for thermal reasons) to form well-defined amorphous regions of the desired length (see Fig. 1). The power level  $P_{erase}$  is used to form the crystalline regions between amorphous marks. The optimum recording powers ( $P_{write}$ ,  $P_{erase}$  and  $P_{bias}$ ) depend on the disc, the recorder and the recording speed. Their values for individual disc/recorder combinations and different recording speeds are determined by the Optimum Power Control (OPC) procedure.

Figure 4a

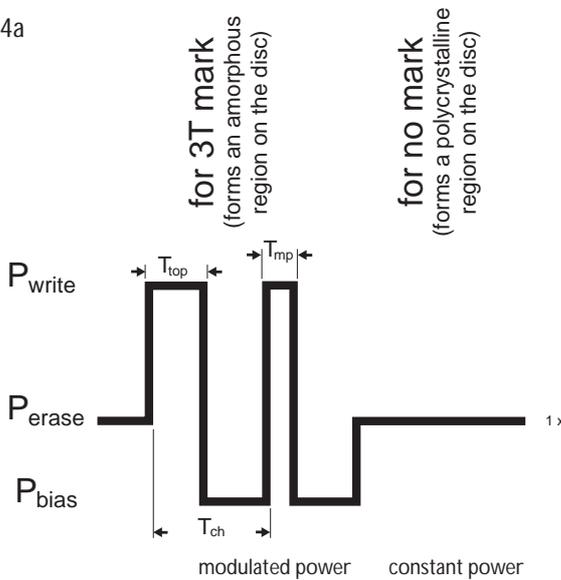


Fig. 4a. Write strategy example. Shown here are the laser modulation strategy to record the shortest 'pit' defined in the DVD system, the '3T mark', and the strategy to record 'no mark'. Recording a mark means creating a low-reflectivity (amorphous) region in the active layer; recording no mark means creating a high-reflectivity (polycrystalline) region as illustrated in the graphs.

Note that new data is simply written over existing data in a single pass. DVD+RW is therefore known as a Direct Overwrite (DOW) system.

Figure 4b

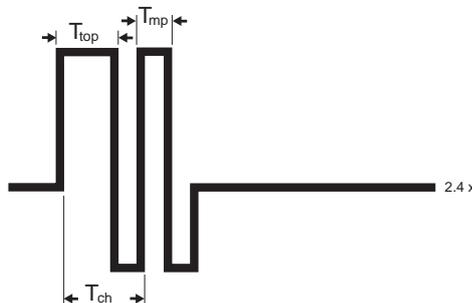


Fig. 4b. Write strategy principle for CAV operation. For good signal quality at both the 1x and the 2.4x speed, the pulse duration for the write pulses ( $T_{top}$  and  $T_{mp}$ ) is kept (more or less) constant over the velocity range. Of course, the channel bit duration ( $T_{ch}$ ) changes with velocity.

This write strategy prevents the recrystallization of the amorphous mark that has just been written. Using this write strategy the disc can be written in CAV mode, but also at any desired CLV velocity between 1x and 2.4x.

## DVD+RW: Lossless linking

In the DVD+RW Video format, video can be encoded with a variable bit-rate (VBR). Because the writing process takes place at a constant bit rate, the writing process needs to be suspended and continued frequently. Normally, this would result in a linking loss, making the disc incompatible with read-only devices like DVD Video players and DVD-ROM drives. With DVD+RW it is possible to perform lossless linking, i.e. to suspend and continue the writing process without linking loss. This feature makes the format very efficient and suitable for random write in data as well as video applications. Additionally, lossless linking makes it possible to replace any individual 32 kB block (recording unit) by a new one, without losing compatibility.

For lossless linking it is necessary to write any data block in the correct position with high accuracy (within 1 micron). For this purpose the groove is mastered with a high wobble frequency (817 kHz at  $n=1$ ), which ensures that the writing can be started and stopped at an accurately defined position. The writing clock as obtained from this groove is very accurate. At the same time, address information is stored in this wobbled groove by locally inverting the sign of the wobbled waveform. For each ERCO block, which is 32 kB, four addresses exist, resulting in a reliable address format with large detection margins.

## DVD+RW: Disc manufacturing

DVD+RW discs are manufactured using equipment similar to that already found in conventional DVD factories, but some dedicated equipment is needed. For instance, the active layer formed by sputtering is amorphous, and has to be converted to the polycrystalline phase by heating it with a high DC power. This process, called initialization, ensures that every new disc reaching users is in the high-reflectance phase. The additional investment needed for manufacturing DVD+RW discs is lower than what would be required for other rewritable DVD technologies.

## DVD+RW: Two-way compatibility with existing DVD drives

An important feature of the DVD+RW disc is its compatibility with existing DVD-Video and DVD-ROM drives. All physical parameters fit within the DVD-ROM specification. The reflectivity is in the same range as the dual-layer reflectivity specification of a read-only disc and the density is the same as for the single layer specification. The main parameters are summarized in Table 1. The choice of identical parameters optimizes playability in current read-only players.

Table 1.  
DVD+RW  
compared with  
DVD-ROM

	DVD+RW	DVD-ROM	
		Single-layer Read-only	Dual-layer Read-only
Media type	Phase change	Read-only	Read-only
User data capacity	4.7 GB	4.7 GB	8.54 GB
Wavelength	650 nm	650 nm	650 nm
Reflectivity	18-30%	45-85%	18-30%
Track pitch	0.74 $\mu\text{m}$	0.74 $\mu\text{m}$	0.74 $\mu\text{m}$
Minimum pit length	0.4 $\mu\text{m}$	0.4 $\mu\text{m}$	0.44 $\mu\text{m}$
Modulation	>0.6	>0.6	>0.6
Data modulation/ECC	8-16/RS-PC	8-16/RS-PC	8-16/RS-PC
Channel bit-rate	26.16 MHz	26.16 MHz	26.16 MHz
Scanning velocity	1x – 2.4x	3.49 m/s (1x)	3.84 m/s

## DVD+ReWritable and how it works

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