ODC WHITE PAPER

OPTICAL DISC CORPORATION

CDR-ROM™ OVERVIEW & IMPLEMENTATIONS

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INTRODUCTION

Optical Disc Corporation (ODC) has recently announced a new media-based product offering, the CDR-ROM. Following its tradition of offering technically challenging formats, such as recordable LaserDisc, one-off DirectCut™ DVD, HD-VCD and various other special formats, ODC believes that time has come to introduce this product to the market. By making the technological bridge between replication and duplication, it is expected that the CDR-ROM product will be a key element in allowing implementation of otherwise impossible features, which could transform the methods of traditional digital content distribution, management and protection.

PRODUCT

The CDR-ROM product is basically a hybrid CD-R disc combining an unalterable mastered user ROM area and a recordable write-once user area. This combination thus allows mass production of proprietary data through a conventional disc replication process, with the added flexibility to append to the disc content through a conventional CD-R recording process. Mastered ROM data can be of any format and type as supported by the mastering encoder and can span across multiple sessions. This flexibility allows one to encode non-standard formats, such as special copy protection schemes, as required by the application content. Recorded user data can contain any data format and type as supported by the recorder and as dictated by the mastered sessions. Recording is possible on any standard CD-R recorder.

The concept for such a hybrid disc was first presented in 1990 within the Orange Book, published by Philips and Sony, which described the specification for the recordable disc. In it, the term “hybrid” was used to describe a particular case of a recordable disc, one which had a mastered area and a recordable area.

Nowadays, however, the term “hybrid” is most commonly used to describe other dual format optical discs, such as one containing PC and Macintosh file structures, or one composed of a CD and a DVD layer. For this reason, ODC has decided to use the term CDR-ROM to describe its incarnation of the CD-R hybrid, a format which still stands nearly unknown over a decade after its first description.

A few years ago, Kodak introduced the CD-PROM product, which was effectively a hybrid disc in the Orange Book sense. It was originally intended for picture storage in the recordable area, whereas the mastered area contained picture viewing and manipulation software. It is to be noted that CD-PROMs were intended to be recorded only through special/proprietary recorders (as found at Kodak’s licensed photofinishers) and were typically distributed to the end user in a non-appendable state.

SPECIFICATION

The CDR-ROM conforms to all physical and logical parameters prescribed by the Orange Book, thus guaranteeing medium readability and recordability vis-a-vis standard readers and recorders. The specification describes parameters of an unrecorded disc and parameters for a recorded disc. The mastered area of a CDR-ROM conforms to the latter set of parameters. In contrast, standard CD-R manufacturing would typically not be concerned with part of the specification describing the recording process and governing rules. The latter are assumed to be followed by the recorder manufacturer and cover items such

as encoding of the user data, recording rules governing the linking of various recording sessions, correct usage and encoding of restricted recording areas, implementation of write strategies for best read-back signal jitter and control of overall read-back signal levels for uniformity across various recording sessions and the entire disc. In the case of the CDR-ROM disc, all these parameters need to be within specification, whether derived by a mastering process or a recording process.

This requirement imposes coexistence of two radically different physical structures on a CDR-ROM disc, the *rom structure* and the *recordable structure*.

CONSTRUCTION

At the manufacturing level, the CDR-ROM is constructed using the exact same streamlined processes and steps as in the case of a CD-R disc. These processes result in a finished disc with a layered construction, composed of a polycarbonate substrate, followed by an organic semi-transparent heat sensitive dye layer applied through a spin coating process, a reflective metal layer applied through a metal sputtering process, and finally a protective lacquer coating layer. The polycarbonate substrate, derived from an injection molding process using a stamper originating from a mastering process, contains the main physical structures. These vital structures are first created in mastering, by a laser beam recorder, on a glass master.

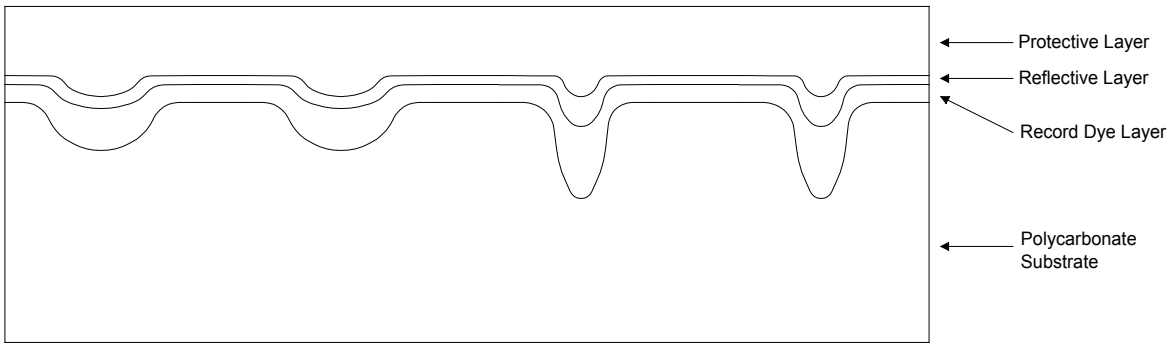

Figure 1. Layered Construction of CDR-ROM disc
Shallow and wide pre-groove neighboring deep and narrow embossed pits

Drives use the effect of these structures on their read-back signals to perform the necessary tasks leading to the recovery of the pertinent information channel. These tasks include focusing, tracking, positioning, and maintaining surface velocity. These two distinct structures repeat at various locations on the disc, as dictated by the required data organization and layout of the disc, creating transition areas along the spiral track at the vicinity where a switch in structure occurs. The major hurdle in creating a CDR-ROM which follows the Orange Book specification, is the ability to produce these distinct structures in a way such that the corresponding recovered signals are electrically uniform throughout the disc.

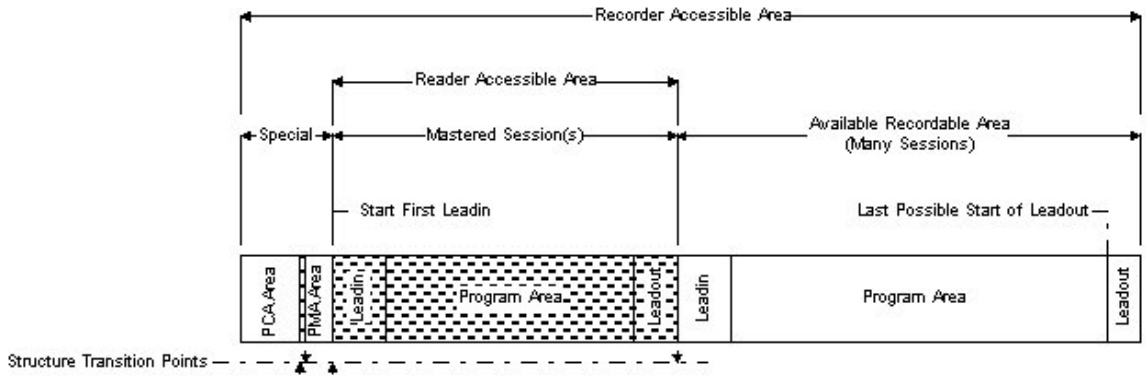

Figure 2. Data layout of CDR-ROM disc
Special area is only used by recorders for write calibration and storage of temporary track information

It is to be noted that the Orange Book specification does not define the geometry associated with each of these structures, but rather their contribution to the optical characteristic of the final disc as measured by defined optical and electronic subsystems.

The recordable structure of a CDR-ROM is created through the formation of a relatively shallow and wide pre-groove, forming (segments of) a continuous outbound spiral track, which is wobbled at a reference carrier frequency. Embedded within this structure is a single information channel, referred to as Absolute-Time-In-Pregroove (ATIP), encoded by frequency modulating the wobble reference carrier. The reference carrier and associated modulation is used by recorders to derive vital timing and addressing information required to perform a recording session. The recordable structure is thus tailored to provide optimum performance for recovery of the ATIP information channel and formation of recorded marks.

The ROM structure of a CDR-ROM is created through the formation of relatively deep and narrow series of embossed pits, following the same contours of the wobbled spiral track. Embedded within this structure are two separate information channels. The ATIP, used by recorders for the same purposes as mentioned above and derived from the wobbled component of the track, and the Eight-to-Fourteen-Modulation (EFM), used by readers to derive vital timing and addressing information required to recover embedded user data. The EFM information is encoded through the relative position and length of the pits along the spiral track. The ROM structure is thus tailored to provide optimum performance for recovery of both the ATIP and the EFM information channels.

	Recordable Structure	ROM Structure
Disc Construction	4 layers: polycarbonate, organic dye, reflective, protective	4 layers: polycarbonate, organic dye, reflective, protective
Physical Structures	Wobbled Pre-groove	Wobbled Pre-groove Embossed pits
Information channels	ATIP	EFM, ATIP
Spindle Control	Wobble carrier frequency	Wobble carrier frequency EFM sync
Addressing Method	ATIP	Subcode-EFM, ATIP
Encoded Data	ATIP	ATIP, PMA, Leadin, Program, Leadout
Linking rules	None	Specified
Synchronization Rules	None	Subcode sync to Block sync Subcode sync to Atip sync Atip sync to Block sync
Recording Method	Thermal decomposition	Thermal decomposition

Table 1. CDR-ROM structures and associated data

MASTERING

Mastering is where the underlying structures for the CDR-ROM disc are created. During this step, a rotating flat glass substrate uniformly coated with a thin layer of a laser sensitive recording surface is exposed to a highly focused laser spot travelling towards the outside of the glass, thus creating the spiral contour of the track. The focused spot is deflected in the radial direction of the spiral, under control of the FM-modulated ATIP signal, creating the wobbled profile. This wobble with the embedded ATIP information is present throughout the master and without any discontinuity. In the ROM areas, the spot intensity profile is modulated under control of an EFM bit stream, thus creating the pitted profile in the tangential direction of the spiral.

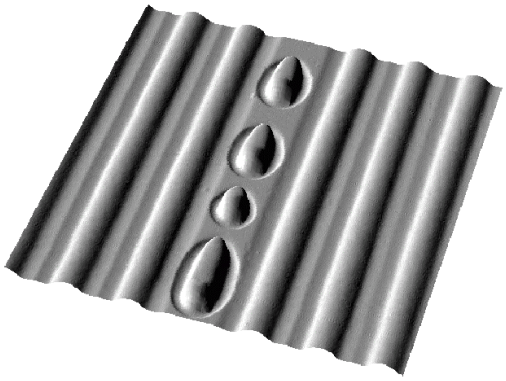

Figure 3. AFM of structures
Pitted PMA track surrounded by wobbled groove

The foundation of a mastering system relies upon its ability to produce an optimum geometry for a given format. Since common formats do not require coexistence of radically different structures along the same track, most mastering systems are designed to create single structures well.

In the case of the CDR-ROM format, the performance of the mastering system is measured by its ability to produce on a single glass master the optimum three dimensional geometry for each of the structures, independently from the other, and the ability to instantaneously switch from one to the other with minimum impact on the produced geometry. This flexibility is not purely a function of the optical and electronics elements within the mastering system, but also and mainly a function of the inherent interaction between the recording material and the intensity profile of the focused spot.

In an ODC mastering system, the focused laser spot intensity profile coupled with the proprietary Dye Polymer recording surface and exposure time, determine the exact three-dimensional physical structure created on the glass master. This flexibility in control coupled with ODC's patented Direct-Read-After-Write (DRAW) technology allow for precise and consistent mastering of CDR-ROM parts.

The ODC CDR-ROM capable mastering system is based on a standard ODC Model 5400 LaserWave™ Mastering System, modified with the CDR-ROM specific hardware and software.

Feature	Reason
Record spot radial deflection	These are controlling handles required for formation of the two structures. Ability to precisely synchronize these tasks is imperative.
Record spot tangential modulation	
Instantaneous spot intensity-profile control	
Recording layer response	A deterministic relationship between controlling elements and corresponding formation is imperative.
Control flexibility	Ability to custom tailor structure for best fit with downstream process is imperative for production success.
Consistency/Repeatability	Imperative for production flow and key to profitability.

Table 2. Key Mastering Requirements

TESTING

For manufacturing purposes, the testing of a CDR-ROM is very much similar to testing of a CD-R. There are various test equipment manufacturers which provide adequate tools for this purpose, however, these tools only report parameter values within certain areas of the disc and which affect readability of parts on standard readers/recorders. In other words, all these tools are designed for the purpose of measuring process windows vis-a-vis readability of parts, and not much is provided to measure recordability characteristics (in this case, appendability) or deficiencies of parts. This is a real challenge and one which if left unresolved prior to product launch, could seriously impact record-compatibility of the part.

As we have seen during the development phase, not all recorders behave the same with respect to a given recorded disc. The difference mainly stems from algorithms implemented within the recorder firmware and more specifically the portion which dictates how a specific recorder detects the appendability option of the inserted disc. Some implementations are more forgiving than others, thus masking potential disc problems, whereas some are very demanding to the point that their conformity to the Orange Book specification has even been challenged. This lack of consistency in implementation is the direct result of lack of a related hardware specification, but one which has to be understood and satisfied for obvious compatibility reasons. Although it is impossible to guarantee 100% compatibility with entire installed base of recorders, one can expect CDR-ROM compatibility performance similar to better grade blank CD-Rs.

Measurement	Type
Continuous ATIP analysis in PCA, PMA and Leadin areas	Physical
Analysis of ALL Synchronization Rules	Physical
Analysis of PMA area	Physical and logical
ATIP vs. EFM Subcode Consistency	Logical

Table 3. Key Tests for Recordability
Full analysis of Special area (Fig 2) is primordial

IMPLEMENTATIONS

The following highlights some implementation examples for ODC's CDR-ROM product, taking advantage of its universal recordability. Some implementations are geared towards enabling of new techniques to help content owners and end users to better organize their material (electronic files). Other applications are geared towards security and safeguard of proprietary material from illegal use and/or distribution, whether the material is readily stored on the physical disc itself or to be made available through other electronic distribution channels, such as Internet, kiosks, etc…

Mentioned applications also take advantage of increased market penetration of new electronic devices, such as PC based CD-R recorders, digital cameras and scanners, which bring desktop publishing, digital imaging and other storage hungry applications into the hands of consumers. In this context and coupled with the booming CD-R duplication business and associated limitations, ODC's CDR-ROM is well positioned to attract interest in many areas.

It is to be noted that although the Orange Book specifies the CD-R/Hybrid disc to be of a circular shape, for the sake of portability and practicality, all the proposed implementations are compatible with modified shaped discs, which are nowadays common.

Mass Storage (Cataloguing)

In its simplest implementation, the CDR-ROM could be used as an end user recordable disc with application files stored in the mastered session. Software publishers and distributors could use the CDR-ROM medium as a means to allow the end user to keep the main application and related user specific data on the same medium. If desired by the application software owner, the mastered session could include any of the available copy protection schemes in order to protect illegal copying of their material. Furthermore, the master application can also be designed to exclusively run from within the CDR-ROM disc, so to "encourage" the end user to purchase the packaged product.

Presented below are a few examples of which many other of similar nature could be imagined, all taking advantage of the powerful end user recordability in multiple sessions feature that ODC's CDR-ROM allows. Ultimately the end user could catalog all his/her application data, together with the main application program, on self-contained application specific CDR-ROM discs, whereas the application program owner can profit from sales of their proprietary applications included within the mastered first session of each disc.

Implementation Examples:

- A main program and associated installation files are stored in the mastered first session. The recordable area is to be used by the end user for storage of related program patches as made available through the program developer's web site. This allows the developer to reduce or eliminate the replication of new discs with each new patch or program version, and benefits the end user by consolidating all related program material within same disc.

- A picture manipulation software is stored in the mastered first session, and end user pictures recorded on subsequent sessions. This is an extension of what is presently available on the market, with the advantage of end user recordability in multiple sessions.

- A computer system backup/restore software is stored in the mastered first session, which would allow the end user to create multiple backups of his/her system at different times. Subsequently, using a single CDR-ROM disc, the end user would be able to restore his/her system to any of the backed up configurations.

- An audio compression/conversion/player software is stored in the mastered first session, and end user generated or downloaded compressed audio files (MP3, LiquidAudio, WindowMedia, etc...) in the recordable sessions. The end user could store hundreds of audio tracks within a single CDR-ROM, and playback at will from the same medium, on any computer platform supported by the application.

Product Serialization (Identification, Expiration, Single PC play,…)

In this implementation, certain software components and associated data are encrypted using a set of encryption keys prior to being written, along with other related components, in the mastered first session. By recording valid decryption keys and initialization data within the recordable area of the disc, specific applications and/or features can be unlocked by the security check software component stored in the mastered session, and thus made available to the end user.

Although the concept is not new, the novelty and advantage to this approach is the fact that the information required to unlock the disc content (or part of it) is to be recorded onto the disc. This information can be recorded directly by the end user or at a distribution point, with the possibility to be updated (recorded at different times in different locations of the disc), thus allowing gradual unlocking or locking of data, leaving an indelible physical trace of these events within the disc. This provides a secure and controlled method to disc data access not attainable by present methods which mainly rely on decryption keys being stored on re-writable medium such as hard disk. The latter method is very prone to tampering, since once the storage location of the decryption keys is known, it can be modified.

The security check routine, which is stored in the mastered session, grants the end user access level to the data stored in the first session of the disc, based on the keys and other related information stored in the recordable area. Amongst other, this information can contain:

- Individual data keys: To be used to grant access to selected data.
- Date limit: To indicate expiration of access. This can be bundled with payment schedules.
- Password: To lock usage of disc. This can be selectable by end user and forced upon for security purposes.
- User Identifier: To detect registered owner(s) of disc. An added security for online transactions.
- Hardware Identifier: To restrict usage of disc on only selected hardware.

The same security routine can be used to manage, format, and generate this information prior to be recorded (updated) onto the disc.

Implementation examples:

- A software company can use ODC's CDR-ROM product to store several of their applications or data files in the first mastered session. For further protection, the software company can decide to include copy protection for the mastered session. Upon initial installation of the disc, all or some of the applications can be made available for a limited time. Through an online transaction, an end user with a CD-R recorder has the option to unlock or permanently enable the application(s) of his/her choice.

- An electronic publishing company can use ODC's CDR-ROM product to store several electronic-books or compressed audio files (MP3, LiquidAudio, WM, etc…) or other…and related application software (playback and catalog) in the mastered first session and distribute via direct mail or kiosks. The end user can review catalog content on the disc, select pieces of interest and order online or through kiosk. The end user has always the option to expand access to available data and only pays when he/she desires to unlock a selection.

- A banking institution can use ODC's CDR-ROM product, cut in a small "business card" format, as a physical "key" to grant its employees access to various company PCs. Access can be controlled via any of the above-mentioned elements (date, hardware, group, password, etc…) and managed by the network security manager who is also in charge of recording the "keys." In this case, there is not much user data in the mastered first session, besides the security check routine that auto-launches once the card is inserted in a PC. Only the network security manager can record on these cards, everyone else uses it as read only. This can be done by encrypting the hardware identifier of the security manager recorder station within the pre-mastered first session, and then matching it against one included within the information in the recorded session. Any mismatch would result in unusable "keys."

- A government agency can use ODC's CDR-ROM to share vital data only with certain individuals within the agency. This can be done by including the data, along with security check routine in the mastered first session, and subsequently record individual hardware identifiers prior to distribution. Without the hardware identifier file being present (recorded), the security check routine would render the disc unplayable. Along with the individual identifiers, other information such as expiration date and password can be included and thus checked by the security check routine.

Product Customization (Direct Marketing, Game Individualization,…)

This is a particular case of the product serialization scheme, whereby the recorded serialization data is mainly used to customize the appearance of the data accessed by the end user, the bulk of which resides within the mastered session. In this scenario, the main application stored within the mastered session merges information stored within both the mastered and recorded area to create what seems to be a unique and individualized set of data. Applications include direct marketing whereby individualized greeting messages can be displayed, to PC games were character names and appearances can be customized.

Copy Protected CD-R

Most copy protection schemes applied to CDs and intended for deployment on standard off-the-shelf players, use pre-fabricated error patterns on the CD in areas that do not affect the user data, as a signature to validate authenticity of the disc, thence allowing the main applications to launch. Since standard CD-R recorders cannot re-generate these errors, illegal copies of these protected CDs are rendered useless, even though all user information may be stored on the illegal copies. Presently, implementation of such schemes is only made practical through a glass mastering process, where the controlled error patterns along with the user data are encoded via special signal processors, creating masters which in turn are used to mass produce copy protected CD replicas. There are several disadvantages to this approach. First, one has to find a facility that can handle the desired copy protection scheme, not all facilities do. Second, the content owner needs to provide the content to the mastering facility, thus becoming exposed to content theft. Finally, product turnaround time and minimum quantities imposed by the replication houses could render this method very impractical and expensive when only few samples are required.

In the proposed CDR-ROM implementation, the glass mastering is merely used to encode error signatures and an eventual copy protection utility tool in the first mastered session. The latter is to allow the end user the option to apply copy protection on his/her own to-be-recorded material using the pre-recorded error signatures. Copy protection could be applied to material recorded within any session. The protection tool need not be stored within the first session, as it could be provided to the end user separately. As total pre-mastered data within the first session is relatively small (kilobytes to few megabytes), this medium provides recordable capacity comparable with standard CD-Rs, with the added capability for copy protection of the recorded proprietary material.

This implementation could be of great interest to individuals and institutions who need to share their proprietary information with others, but are concerned with reproduction and the disadvantages mentioned above. This could be the case for software companies sending out test software; government agencies and financial institutions desiring to share proprietary material within various departments or groups; architects, advertising agencies and consultants desiring to send out unfinished work for customer review, or even software distribution kiosks creating on demand finished products with the added security of copy protection.

CONCLUSION

With this document we have attempted to introduce the CDR-ROM product in relatively easy to understand terms; from its origins in its definition by the Orange Book, through its underlying technology and inherent manufacturing and development challenges, and finally to some attractive implementation examples. The main goal was to try to show why this potential product has been dormant for so many years and why here at ODC we have decided to finally make it available. By raising product awareness in the eyes of relevant industry organizations, format developers, software developers, content owners, publishers, duplicators, copy protection developers and recorder manufacturers, we believe that we can make this format popular by filling in some of the gaps between replication and duplication. Although recordable DVD media are also becoming more accessible and stable, we also believe that through its unique applications the CDR-ROM has the potential to extend the life of recordable CD media many years. In turn, this would certainly shape the way standard content distribution will be done and pave the way for equivalent approaches applied to recordable DVD and higher density media.