WHITE PAPER
SUMMARY

VMD

TECHNOLOGY

VERSATILE MULTILAYER DISC

Advanced Optical Storage Technology for Discs and Drives

VMD TECHNOLOGY
WHITE PAPER (SYNOPSIS)

Versatile Multilayer Disc (VMD) is a next generation optical disc standard, designed for High Definition content - motion pictures, video on demand, sports, gaming, and all video content and data.

VMD has a storage capacity several times greater than current Digital Versatile Discs (DVD). Its capacity is also greater than presently developed DVDs employing blue laser.

Commercial production is based on inexpensive commercial red lasers used in conventional CD/ DVD and therefore has the advantage of simplicity in disc and drive manufacturing.

Applications of the VMD technology are also discussed in this Paper; centered on the manifest need for greater storage capacity occasioned by the worldwide transition to digital high definition video and cinema.

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NEW MEDIUM ENTERPRISES

VERSATILE MULTILAYER DISC - *VMD*

Introduction

This is a summary of the technologies involved and the processes required to produce a VMD, which may be played back when inserted in a VMD player or driver unit, whose output is fed to a high definition display in the home or in a theater.

VMD technology does not impose any fundamental change on current DVD manufacturing processes nor in the way in which content is replicated. The VMD drive is very similar to the standard DVD player, there being only small modifications needed for the multilayer readout option. Thus, the production of both the drivers and the discs themselves could be initiated at existing DVD manufacturing facilities with a minimum of upheaval. For that reason, VMD can be presented as an upgrade, offering considerable added value, without comparable increases in production costs.

As was mentioned above, the worldwide TV and feature film market is ready to introduce high-definition TV (HDTV) to the Home Video market. However, the present CD/DVD industry cannot produce an optical disc that complies with the HDTV technical requirements.

Optical and mechanical limitations make it impossible for single or double layer DVDs to achieve the required increase in storage capacity. Whereas through a unique process of multi-layering the VMD has been able to dramatically increase the disc storage capacity while at the same time retaining flawless playback quality.

The Technological Highlights of VMD are:

* Format is suited for High definition content
* Technology is based on existing 'Red Laser'
* Multi-layer structure increases capacity of media
* VMD 'Player' hosts all standard formats
* Prices are comparable to present DVD products

INDEX OF TOPICS

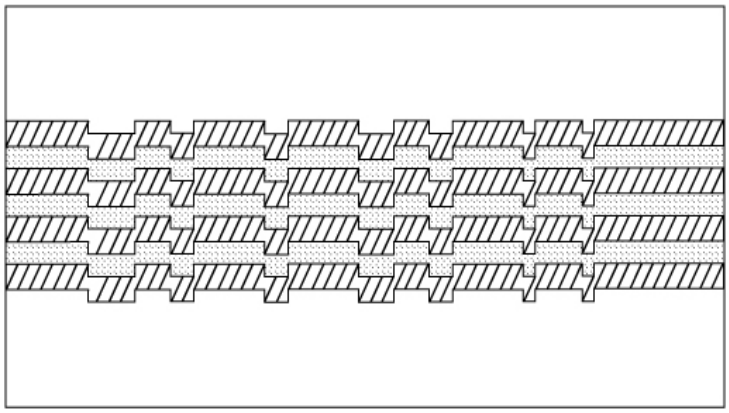
The Versatile Multilayer Disc

The VMD is precisely the same size and thickness as a DVD. The Disc consists of a number of information layers on which video data is imprinted by information carrying masters, or stampers. Intermediate layers separate the information layers, and all are bonded together to form a single optical disc – the 'Versatile Multilayer Disc' or VMD.

The key word is 'Multilayer'. Here lies the basic difference from DVD. The DVD comes as a single (information) layer DVD-5 (disc) containing 4.7GB storage capacity and two layers one sided DVD-9 containing 8.5GB storage capacity. There are also double sided DVD-14 and DVD-18. Double sided discs means that the information layers are from both sides of the disc. In order to read the other side you have to flip the disc in a player.

VMD has at least 4 information layers from one side of the disc. The four layers VMD-20 contain 20 GB storage capacity on one side of the disc. It is technically feasible to have 10 layers on a single side.

Structure of 4-layer VMD disc



During the last years, attempts were made in the field of DVD technology to increase the capacity by increasing both the recording density in a layer and the number of layers. It is well known that to increase optical information capacity, one should:

- **Decrease the wavelength of reading/recording laser radiation**
- **Increase the numerical aperture of the lens**
- **Increase the number of layers on the disk**

The techniques listed above presented serious technological challenges that have been successfully overcome by the developers of VMD.

Extended Life for DVD

The current VMD is based on Red Laser technology and assures a long life ahead for the Red Laser infrastructure. As a result Red Laser technology has many years of service remaining, providing discs with sufficient capacity to rival any promised Blue Laser based format. No technological need exists that would validate refurbishing the entire DVD infrastructure to change to the costly Blue Laser in the foreseeable future.

Each information layer in VMD is manufactured by replication-like technology using standard DVD stampers and machinery. Unlike in the case of the present conventional reflection discs, in VMD, interlayer cross talk is drastically diminished. It is this cross talk in particular that establishes the 2-layer limit for DVD. VMD technology solves the problem of interference between layers (cross talk) that is currently inherent in DVD, and provides the basis for multi-layer optical data storage.

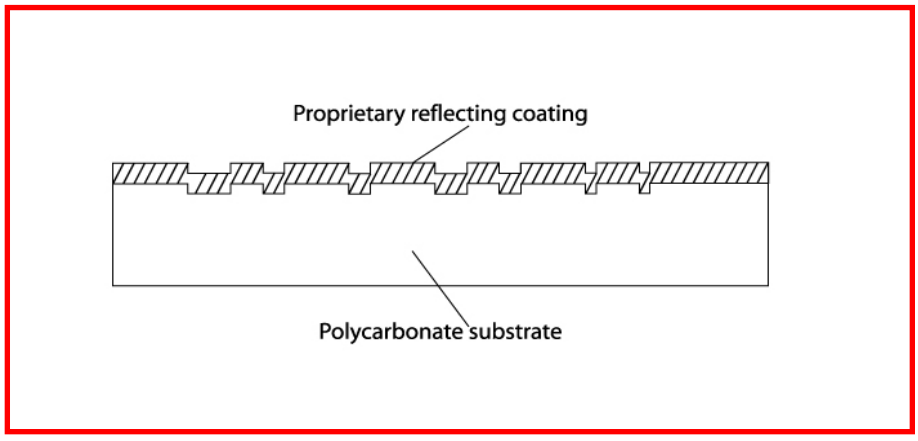
VMD technology (as well as DVD technology) is based on polymer materials (polycarbonates), hence the manufacturing price per unit will be close to that of DVD.

In VMD manufacturing, initially a pattern-carrying polymeric master with information pits in a form of micro cavities is manufactured, by using the traditional methods of injection molding or photo polymeric replication, after this, on its surface, a partially reflective layer is deposited.

VMD consists of few information layers deposited on a base layer - substrate. In each of these layers, the information is recorded in a form of pits. A separating layer holds definite distance between neighboring information layers. The intermediate layers are formed with application of so-called 2p technology. It is a very simple process implemented on the usual DVD bonding machines.

The VMD multilayer structure is laid on the substrate manufactured from a material of high optical quality that also is endowed with necessary mechanical properties to the product as well. Each VMD information layer is manufactured separately. To produce a layer, it is necessary to have an information-carrying master

Note: *Only the first and the last information layer require masters made of nickel, while the intermediate layers are stamped by plastic replicas; one plastic replica is good for stamping hundreds and thousands of discs.*



Encoding, Compressing and Controlling

Specific software algorithms are used, by which video information is compressed to fit the available physical storage capacity, encoded and imprinted on the masters/stampers and thereafter imprinted on the discs. These algorithms are called codec.

The most widely used codec is MPEG-2 format. But there are others, like MPEG-4 and Windows Media 9. Many claim that they have a codec better than MPEG-2 and this allows them to compress video information more effectively than using the popular MPEG-2 algorithms or format.

More compression means that one can save on a physical storage space of the disc and imprint on the disc more video data. Without arguing the merits of one codec against the other it is absolutely clear that more physical capacity on a disc is what everyone is after. No better compression algorithms will ever substitute for physical space. As the demand for higher video quality inevitably grows so must the physical storage capacity of the disc.

Technically, the encoding and compression is done by a piece of hardware called ENCODER. This device encodes and compresses in real time. 150 minutes length movie will be encoded compressed to fit the disc in exactly 150 minutes.

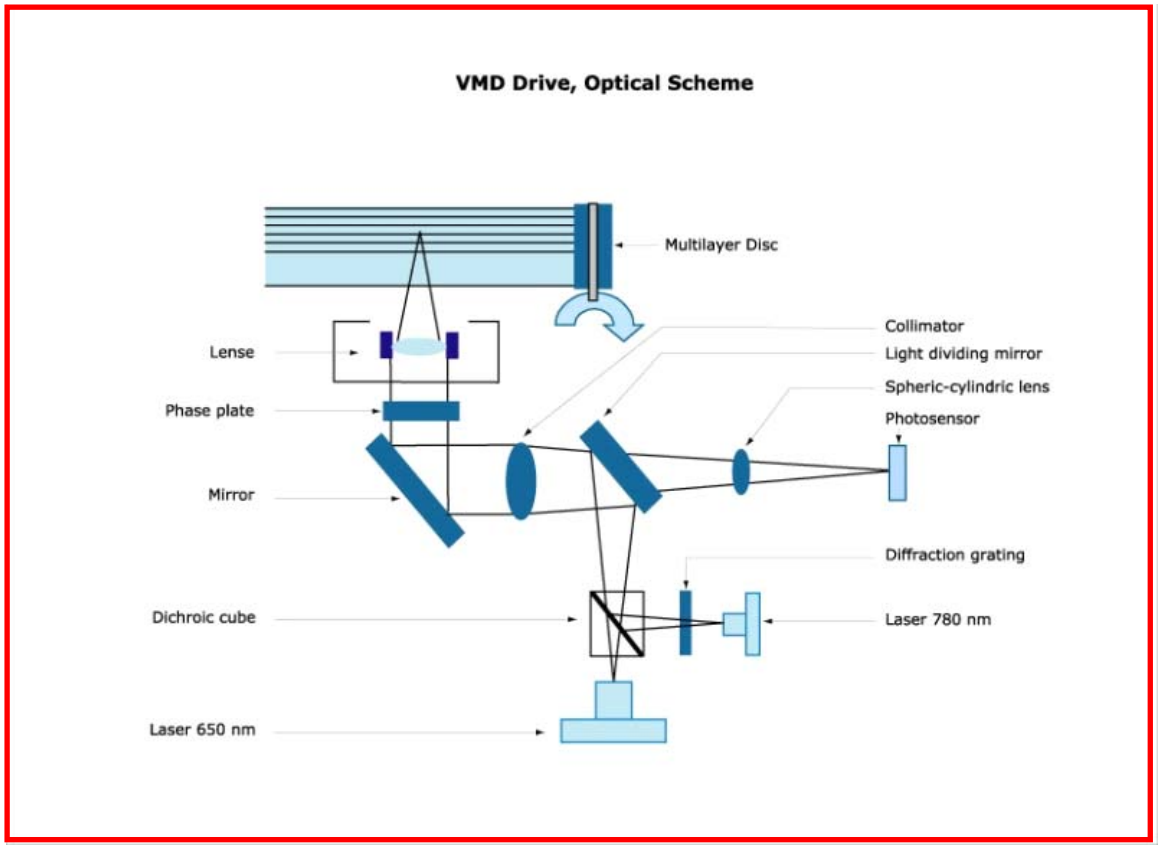
There is also software technical data that should be imprinted on optical discs that enables the player to recognize its position on a disc (longitudinal and transversal), the identity of the information layer which is being read, the transparency of the information layer for disc authoring, and many other service commands, subroutines and metadata.

The VMD Player (& Drive)

The mechanical system varies considerably among different manufacturers. The VMD Player can be assembled with components of recent versions of DVD players with minor technical enhancements.

The main difference and advantage of VMD player over DVD is that it is endowed with so-called HD Decoder. HD Decoder enables a viewer to watch a real High Definition quality video. ‘Decoder’ is an electronic circuitry that receives the encoded digital information from the disc, and converts it in real time into video information on the screen. In modern players all the chips and service circuitry are placed on one electronic board inside the player unit.

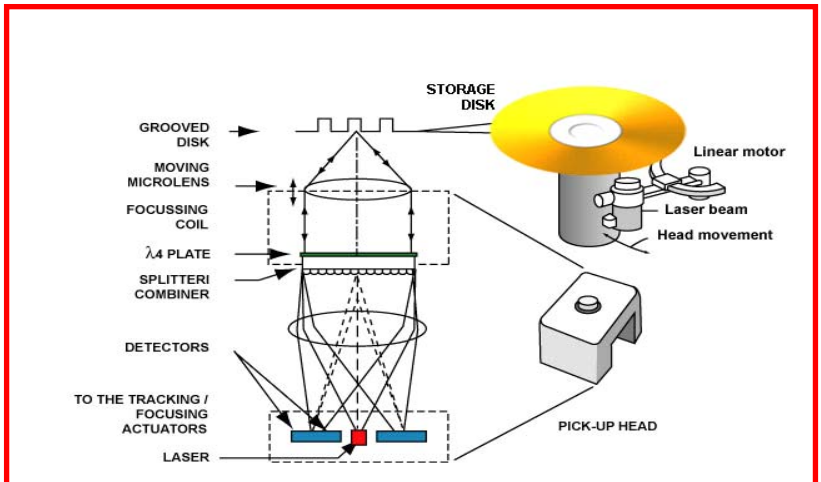
Every DVD player contains a standard DVD Decoder. But the HD Decoder could process 4 times greater video data flow with four times speed than the usual DVD Decoder. Due to increasing demand for HD Video, various semiconductor companies are now developing HD Decoders.



There are three examples of commercial players using HD Decoders. Two of them are associated with so called 'Blue Laser' technologies developed by Sony, Toshiba, Philips and others for HD applications. VMD at this stage is not concerned with blue laser technologies. They are complicated and expensive for consumers.

The third example is found in the 'EVD Player' developed and commercialized by a Chinese company Beijing E-World. As already indicated VMD uses 'Red Laser' technologies. To achieve HD Video within the framework of Red Laser technology; VMD has acquired and incorporated the high quality HD Decoder developed for EVD.

NOTE: *The HD Decoder is required for 'stand alone' VMD players only. However the computer embedded VMD drive does not require Decoder at all. The decoding is done by commercial software installed on the computer.*



The VMD Drive

Pick-Up Head: Another vital component of the VMD player is the Optical Head *(pick-up)* that includes lasers, mobile actuators and lenses for picking up the reflected laser beam and passing it over to a multifaceted photodiode receptor which receives the signal from the VMD disc. VMD players require high quality optical *pick-ups*. Not all DVD *pick-ups* can be used for VMD player.

A CPU (Central Processing Unit) controls all the functions of the player. Software 're-programming' is required to enable the CPU to recognize the Multilayer structure of VMD - instead of two layers of DVD. This is a crucial element in the VMD technology framework.

VMD Applications

The fact that VMD has so much more physical storage capacity than DVD makes it the ideal choice for a whole array of applications:

1. The simplest niche application for VMD is recording of several feature films on a 'single' disc or in other words - *several DVDs could be copied on to a VMD.*

2. VMD enables mobile storage of large software applications and data bases for industry, construction, design, etc. Such software would sometimes need to be transported on hard discs or several DVD's. (Suitable for all pre-recorded data storage four or eight times larger than DVD).

3. High Definition (HD) TV and Digital Cinema - HD means that the quality of video that consumer sees on a TV screen or computer display is much superior by comparison with Standard Definition (SD). The basic concept behind high-definition television is actually not to increase the definition per unit area but rather to increase the percentage of the visual field contained by the image.

The quality of a video is primarily determined by the number of pixels for digital video (or lines for an analogue video) that our eye sees on a screen. If the screen is genuinely high definition it means that it has at least 1080 horizontal lines with 1920 pixels in each line. Video data is viewed on a screen with such resolution is called HD 1080 video format. This format is 4 times more resolution than the one provided to a viewer by DVD. Thus it is quite obvious that VMD could provide the high resolution content by virtue of the greater storage capacity.

4. Another important area is sophisticated computer games with high resolution 3D graphics. Imagine a new computer game such as Star Wars that requires more than two DVD discs and subsequent necessity to substitute them during the game in a computer slot. With VMD technology the same game or even two such games will be on one single side disc with the same retail price. Furthermore VMD's huge storage allows creating a new generation of computer games with ultimate, truly life like 3D graphics.

VMD vs BLUE LASER

The Key Issues

1. **Blue-Ray and HD-DVD; both use blue lasers, which operate at lower wavelengths (405 nanometers) than current red lasers (650 nanometers). The only common feature among them is 'blue laser' (meaning wavelength 405 nm).**
2. **Both HD-DVD and BLU RAY are closed formats, to each other and others, explicitly played on entirely different players. Both discs and drives are manufactured using entirely different technologies.**
3. **To produce a Multi-player that can handle both Blue-Ray and HD-DVD formats in one machine it would need two pickup heads, and therefore would become very expensive.**
4. **Higher Costs of HD-DVD or Blue-Ray is primarily because of different machinery and equipment with entirely different tolerances.**
5. **The VMD Player can be assembled with components of recent versions of DVD players with minor technical enhancements.**
6. **Each layer of HD-DVD (15 GB) and Blue-Ray (25 GB) has greater capacity than standard DVD but the technology involves higher production costs and therefore it makes more sense to go with existing low cost Red laser VMD technology to increase storage capacity.**
7. **Lower Cost of VMD - It is typical overkill to create a completely new production infrastructure (such as in blue laser) for manufacturing discs and players to come up with capacity of 15, 20, 40 or even 50 GB. VMD Technology can provide these storage capacities with the existing Red laser infrastructure at NO EXTRA COST.**
8. **The key word in VMD is 'Multilayer'. Here lies the basic difference from DVD. VMD technology allows building disks (and compatible players) with 5, 10 up to a maximum of 20 layers.**
9. **VMD takes advantage of all available formats with its MULTILAYERING technology – VMD technology caters to both - red laser and blue laser.**
10. **Eventually, 'Multilayer Blue Laser Discs' will be based on VMD technology.**
11. **VMD is the only technology that has actually demonstrated 'multilayer' capability.**
12. **Existing DVD players cannot read 'Multilayer' discs; whereas VMD is fully backward compatible and can play all the previous formats – CDs and DVDs.**
13. **The VMD Player is designed to also read 'Enhanced Versatile Disc' - EVD (Product of Beijing E-World)**
14. **The VMD player also uses an 'HD Decoder'. The HD Decoder enables viewing of High Definition quality video.**

OPTICAL DISC COMPARISON CHART

FEATURES Attributes & Parameters	DVD Digital Versatile Disc	VMD Versatile Multilayer Disc	HD-DVD High Density DVD	BD Blu-Ray Disc
Technology	Red Laser	Red Laser	Blue Laser	Blue Laser
Disc Diameter	120 mm	120 mm	120 mm	120 mm
Disc Thickness	1.2 mm	1.2 mm	1.2 mm	1.2 mm
Centre Hole	15 mm	15 mm	15 mm	15 mm
Laser Wavelength	650 nm	650 nm	405 nm	405 nm
Numerical Aperture	0.6 & 0.65	0.65	0.65	0.85
Track Pitch	0.74 µm	0.74 µm	0.4 µm	0.32 µm
Shortest Pit	0.4/0.44 µm	0.4 µm	0.2 µm	0.15 µm
Jitter	7-8 %	4-5 %	6-7 %	4-5 %
Data Layers/Side	2	10	2	2
Layer Capacity	4.7 GB	5 GB	15 GB	25 GB
Maximum Capacity	8.5 GB / Side	50 GB / Side	30 GB / Side	50 GB / Side
Data Transfer Rate	11 Mbps	40 Mbps	36 Mbps	36 Mbps
Content Protection	CCS, 40 bit	VMDCPS,1024 bit	AACS	AES
Encoding	MPEG-2	H.264, VC-1, MPEG-2 & 4	H.264, VC-1, MPEG-2 & 4	H.264, VC-1, MPEG-2 & 4
Video FPS	480, 576/24p, 50, 60i	1080/24p, 50, 60i	1080/24p, 50, 60i	1080/24p, 50, 60i
Compatibility	CD	CD, DVD, EVD	---	---
Mfg. Plant	Facilities Already Existent.	Minimal DVD Plant & Process Adjustments for VMD conversion	Significant DVD Plant Machinery & Process change required	Totally new infrastructure, machinery & process
Per Unit Disc Cost	0.5$	0.65$	Not Known	Not Known
Availability	Available	4Q 2005	Not Known	Available in Japan since 1Q 2005
Future Potential	Replacement expected by new technologies within 2 or 3 years.	VMD currently capable of 50 GB. Future Blue Laser VMD would be 300 GB	Blue Laser Discs imminent in future as storage demand grows beyond 100 GB	Blue Laser Discs imminent in future as storage demand grows beyond 100 GB
User Assessment	Familiarity, Low Prices, Vast Content, Standard Definition Video	HD Video, Greater Storage, Low Priced Disc & Player	HD Video, Greater Storage, High Priced Disc & Player	HD Video, Greater Storage, High Priced Disc & Player
Producers	DVD Forum	New Medium Enterprises Inc	Toshiba, NEC	Panasonic, Sony, Sharp

VMD is Future-Proof considering the fact that it has resurrected Red Laser from early obsolescence by increasing its capacity to an amazing 50 GB without added production cost. Another BIG PLUS is that VMD Technology can eventually be applied to Blue Laser whenever it becomes commercially viable and affordable; thus making it possible to have 300 GB on a single disc – proving that VMD is well ahead of market demand and is in a state of constant readiness for easy transition.

NOTE: *Information compiled from currently available data in public domain*

Piracy - *The Challenge*

Copy protection benefits consumers as well as the industry because without these safeguards, the industry would not be able to release their high-quality digital content for fear of widespread and rampant piracy.

While no technology has yet proven foolproof, the industry continues to implement protection technologies which raise the threshold of difficulty and expense for the pirate and therefore help reduce piracy.

Unlike traditional analog piracy, a digital pirated disc is as pure and pristine as the original. In addition, a production facility can churn out a huge volume of illegal discs in relatively short time.

CONTENT PROTECTION

Full compatibility of VMD with DVD opens the possibility of using all identical copy protection algorithms used in the current DVD industry, in addition to its proprietory data protection features:

Content Scramble System(CSS): This algorithm is a data encryption and authentication scheme intended to prevent copying video files directly from VMD-Video discs.

Content Protection for Prerecorded Media (CPPM): This is an improvement on CSS. CPPM is used only for VMD-Audio.

Serial copy Generation Management System (CGMS): This prevents initial copies being copied (copies of copies).

Content Protection for Recordable Media (CPRM): This is an algorithm that ties a recording to the media on which it is recorded. It is supported by some VMD recorders, but not by many VMD players.

High-Bandwidth Digital Content Protection (HDCP, DVI, and HDMI): HDCP is similar to DTCP, but it was designed for digital video monitor interfaces.

VMD (disc) is endowed with a complex series of multi-level software and hard-ware data protection features. The protection system does not allow copying data from the disc to computer or any other type of data storage.

VMD uses proprietary encryption algorithms based on most advanced methods of data protection much more powerful than the long time broken DVD (video) protection. Importantly the protection system is vastly helped by the multi-layer VMD structure and is intended to solve the analogous protection problems as does CSS, but with much higher reliability.

The level of defense against unlawful copying is so sophisticated that it would require years of labor to compromise it. Such endeavor is not economically feasible. A powerful protection system is absolutely necessary to allay the fears of content providers and studios.

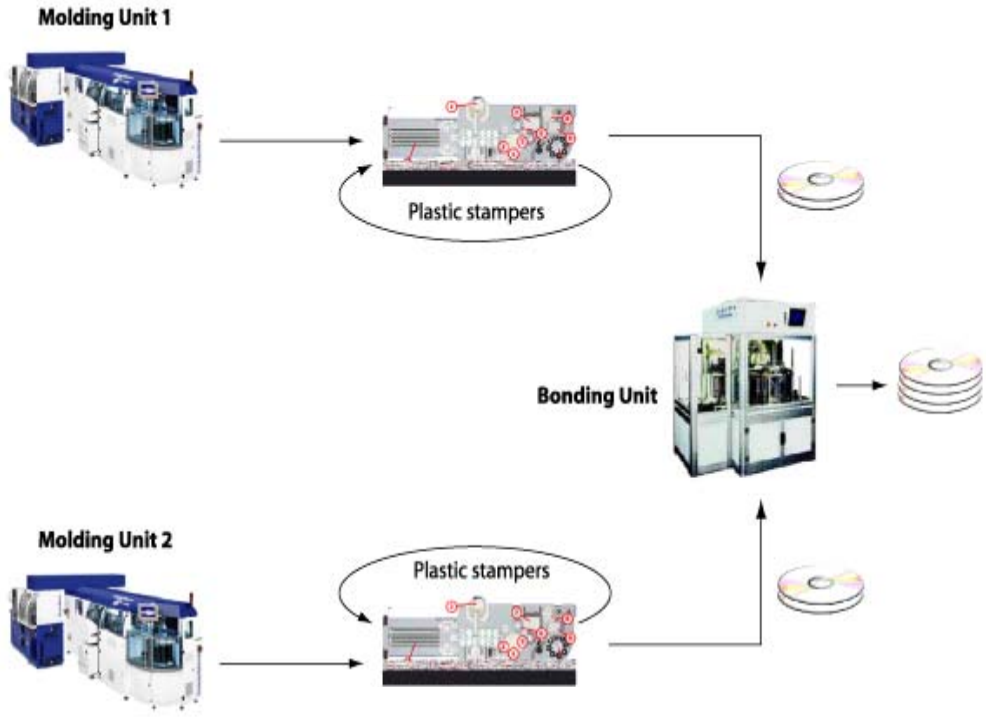
Industrial Production of VMD *(Discs)*

VMD technology is designed to create a disc with many information layers. To be able to read from many layers it is necessary (but is not the only criterion) that the disc be transparent. To have it transparent we have to use different materials commonly used in DVD.

The industrial manufacturing of VMD will be fully possible on the existing DVD manufacturing machines. This is why any established DVD factory (there hundreds of them in the world) will be able to manufacture VMD without costly investment or complicated restructuring of industrial cycle. Because of this the cost of production of VMD will be roughly the same as DVD.

Mass production line for 4-layer VMD based on conventional DVD machinery

(Hypothetical Production Line)



There are several basic processes in making a VMD disc.

The PROCESS STEPS are summarized below:

STEP 1. Two polymer substrates enclose the disc.

They are similar to those used in the DVD-9, but are slightly different in thickness. They are manufactured in the same molding machines as those used for DVDs. The manufacturing process is essentially the same as that used for DVDs. This is identical to DVD.

STEP 2. Imprinting information on the substrates.

This step involves imprinting information on the polymer substrates, and is achieved using standard nickel masters, or stampers. However, the manner in which the information is recorded is very different from DVD, because of the special requirements of the high definition format. The imprinting or casting is done in molding machines. Mechanically, we consider Step 2 as identical to DVD.

STEP 3. Deposition of reflective material on information layers.

This is the most proprietary and critical part of VMD technology. The material is very different from that one used in DVD, which is a metal (aluminium, silver or gold). We use completely different glass-like materials for reflection in order to achieve only 2-5% reflectivity instead of 40-50% reflective as it is in the case of metal deposition. The deposition of this material is done by means of a vacuum deposition process. Fortunately, while this is a change from DVD production technique, by means of small modifications we can use industrial machines that use a similar deposition technique for completely different products (eye glasses).

We managed to adjust the existing sputtering technology used in a DVD production line for the deposition of a different material. This is not a trivial matter, and requires inventiveness and engineering ingenuity. Thus we consider STEP 3 a critical and strongly deviating step from conventional DVD process, albeit implemented on a DVD production machine.

STEP 4. Building an intermediate third information layer.

This is done by a process and from materials also different from DVD. Nevertheless we have learned to use a bonding machine present in any DVD-9 line (because DVD-9 is a disc consisting of 2 bonded layers) for this purpose. While the DVD-9 bonding machine is used for bonding naturally, we shall use it also as a machine for building an intermediate polymer layer (inside the outer layers). We consider STEP 4 as different from DVD, but implemented on a DVD machine for a different process.

STEP 5. Imprinting information upon an intermediate polymer layer.

This is done by using so-called polymer replicas of nickel masters. One nickel master is enough for the manufacture of thousands of such plastic replicas. The technology is somewhat similar to the one used in DVD-18, but involves much proprietary improvement. STEP 5 is implemented using DVD bonding machines and involves important proprietary techniques.

STEP 6. Separating the polymer replica from the layer.

In an automated line it will be effected by a robot. Such robots exist and are used in DVD-18. STEP 6 is different from DVD-9 but intrinsic in DVD-18 production.

STEP 7. Depositing of reflective material upon the inside information layer.

This is done exactly as in STEP 3.

STEP 8. Building of the intermediate inside 4th information layer.

This is done by repetition of STEPS 4 to 7

STEP 9. Bonding together of the top 1st layer with 2nd or 3rd layers beneath.

This is done again using a DVD-9 bonding machine but the gluing and other materials are different from the DVD-9 assembly.

CONCLUSION

This paper aims to provide an overview of VMD as a viable alternative to DVD and as an innovation among new generation optical storage systems.

The author has outlined briefly - key features of VMD Technology and its scope for application in the optical storage market, including the role of VMD in such new "killer" applications as High Definition digital video storage.

VMD technology does not impose any fundamental change either on current DVD manufacturing processes or in the way in which the content is replicated. Thus the production of both the drivers and the discs themselves could be introduced at existing DVD manufacturing facilities with minimal expense; offering considerable added value, without increase in production costs.

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