Dual Layer Recordable DVD

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Introduction

In the race for pre-recorded optical media the most recent offering is Dual Layer DVD+R (DVD+R DL), with a capacity of 8.5 GB of data on a single disc. The contest actually began many years ago when Thomas Edison invented the predecessor of the LP (vinyl Long Play) in the form of a drum with a cut-in continuous track containing the sound. This was directly followed by magnetic recording principle in a metal wire. And, as they say, the rest is history.

What is important to notice is that the pre-recorded formats have always been followed by recordable and, eventually, rewritable ones. Human beings simply need to record data. The recently-introduced DVD+R DL is another very nice and very advanced gadget, and is the result of intensive and tedious technological development.

To remind ourselves: the formulation of the pre-recorded DVD formats covered several options, such as DVD-5 (single-layer, single-sided), DVD-10 (single layer, double-sided) DVD-9 (dual-layer, single-sided), and finally even DVD-18 – dual-layer, double-sided. The numbers in these cases approximately correspond to each disc's capacity in gigabytes.

All these pre-recorded formats were followed by a rather poor standard of recordable and rewritable formats, which primarily could store, at the most, 3.95 GB and were single-sided only. The first rewritable format, DVD-RAM, could store no more than 2.6 GB. In reality, these limitations were simply consequences of the technological constrains at that time. With the existing knowledge, we were not capable of creating reliable recording media with a capacity to match the pre-recorded formats. The growing knowledge within our industry, however, has led to the development of recordable and rewritable formats having a capacity of 4.7 GB – equal to DVD-5.

As we know, two competing formats were created: DVD-R and DVD+R, which continue to struggle with each other to attain the highest possible recording speed. The time of recording that equals 1/8th of the normal DVD playing time has already been reached commercially (time equal 1/16th in research laboratories). However, it is not the recording speed that is the main topic of this article, but the storage capacity.

Reaching the capacity of DVD-9 was, for a very long time, a matter only of speculation. However, it was eventually obtained as a result of very intensive and extensive research carried out within several laboratories.

It appears that DVD+R is the format leading the Dual Layer implementations, with most of the research undertaken by Philips in co-operation with Mitsubishi Chemicals. The Azo type of dye from Mitsubishi, which was already recognized as a high quality one for the earlier CD-R format, appeared to be even better in application to recording DVD related formats. This progress is expanded more by research in the laboratories of Pioneer, Ricoh, Fuji, Sony and other companies involved in Optical Data Storage. In seeing the way that +DL has been received,

Pioneer in particular is very keen to introduce quickly a 'dash' equivalent (DVD-R DL) of the dual layer recordable medium.

Dual layer DVD+R disc design

Implementation of the dual layer to DVD+R formats seems to further consolidate the technological advantage of this medium, already evident in the recording speed race. The design of DVD+R DL imitates that of DVD-9 (see Figure 1). The dual layer discs consist of a substrate with an embossed spiral groove structure, the same type as 'normal' DVD+R. This groove is coated by spinning with the appropriate dye. Restrictions on the dye coating and drying are very much the same as for DVDR media. Then a metal semi-reflective layer must be vacuum coated, or simply sputtered. Crucially, the reflective layer homogeneity over the entire disc's surface should be at least the same, if not more, stringent than for standard DVD-9. Moreover, this reflective film has to fulfil a strict heat conduction condition for good data recording.

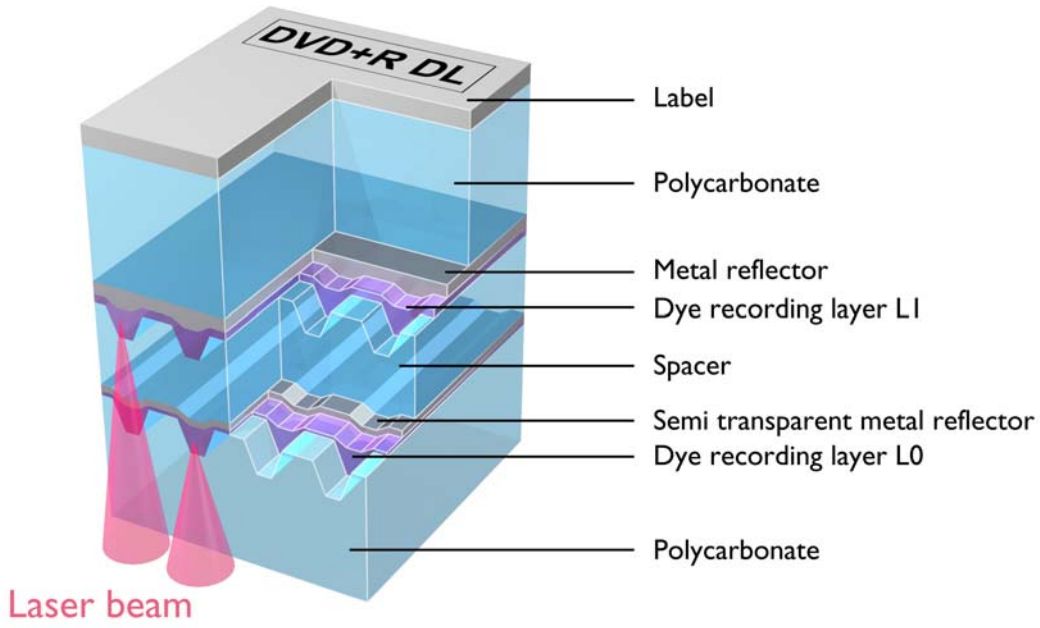

Figure 1. Structure of the DVD+R DL (reproduced with thanks to Philips Intellectual Property & Standards)

The next step is very critical. On top of the first recording stack a layer of spacer resist with, again, a typical structure for the recordable media of spiral groove is applied. The groove is modified for optimization of the recording process. However, one should not expect radical groove geometry changes for this design. The typical process of application of this spacer is called the 2P process. This means using the UV-curable polymer and a transparent, often disposable, stamper. The 2P process, manufacturing structured elements from a photo-curable polymer, has been known and used for many years. It is also a process very much disliked at mass production level.

With this method, the second groove in the DVD+R disc is created as before, and coated with a recording dye, cured or dried, and finally sputtered with a very good reflective metal layer. Since reflectivity of this type of optical media is always an issue, the reflective material has to

be of a very good quality and homogeneity. Such a half DVD+R Dual Layer disc must be bonded to a dummy substrate, very much like its simpler 'brother'.

That, in brief, is the structure of a typical DVD+R Dual Layer disc. The disc looks like a sandwich with a duplicated recording structure. In other words, it looks like one recordable disc which has another, very thin, recording disc placed on top. Recently used 2P technology for creation of the spacer is highly inconvenient. It is expected that there will be other technologies invented for volume production of this type of media. Known optical media manufacturing equipment suppliers are already working on finding practical solutions, and in the research laboratories there is also work going on for a design that will resemble a typical DVD-9. This means manufacturing the two half recordable substrates separately and bonding them together in the last stage of the production. Yet this option, called 'reversed' or 'inverted stack' poses several technological challenges (see Figure 2).

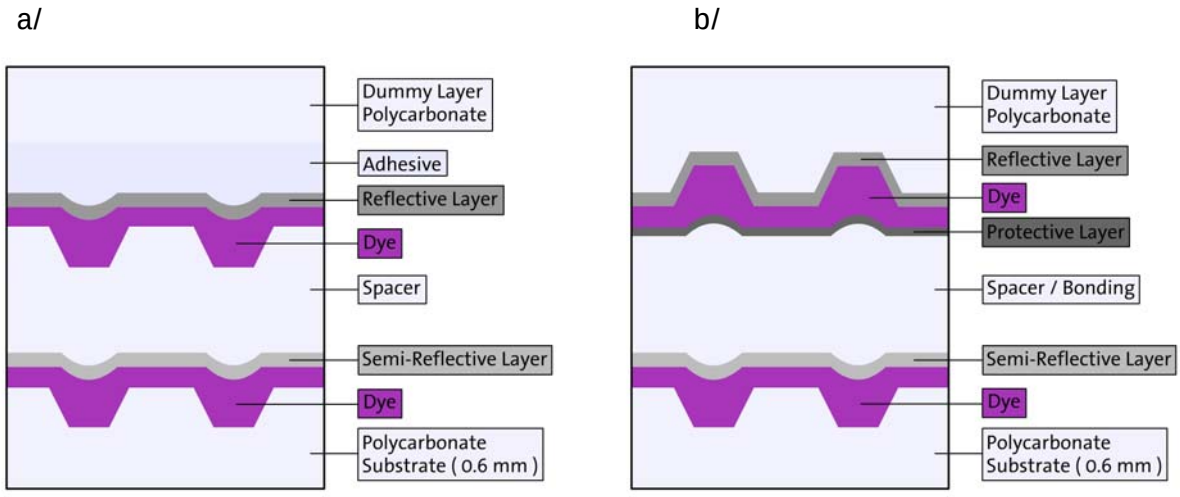

Figure 2. Schematic presentation of `simple' (a) and `reversed' (b) recording stack design for DVD+R DL discs

The principle does work, as several research projects on recordable Blu-ray Disc successfully use the 'reversed stack' for recording. Moreover, we know that the recording mechanism for this new structure is different than for the classical one. Placing the reflective layer inside the groove drastically changes the cooling pattern within the groove, and as a result, the mechanism of the recorded pit formation is different than for the regular DVD+R structure. Furthermore, the dye itself would require protection against direct contact with the bonding material by use of a special film.

This idea of the 'reversed stack' is so different from normal that additional research is needed on groove and dye modification. However, this option is very attractive from the point of view of media manufacturing. It would allow for production of the halves in parallel, to be glued together at the very last part of the manufacturing process, emulating DVD-9. Can this be achieved – or will it stay as a question mark?

At the moment we know that the 'simple stack' works. It uses dye very similar to the one used for single-layer DVD+R. Recorders are also very much alike. The main differences are related to the requirements of high power and minor drive adaptation. One can record this type of disc at

2.4X speed. The recording speed will increase, yet the media will always require more laser power to write than the single layer type. On the other hand, the dual layer disc design substantially limits the quality of recording at 1X speed.

Dual Layer DVD+R format

As we have said, this new format was created to resemble DVD-9. The creation of a recordable equivalent of the pre-recorded format, with the use of elements of the specification of the existing '+R' format is certainly the major force behind the development of this new media. It is obviously very visible in the format definition. An abbreviation of the specification is presented in Table 1.

In order to fulfil the restriction of reflectivity higher than 18 % from each layer, strict tolerances were put on the optical design of the stack. The transmission of the first recording layer (L0) should be larger than 50% to allow for read-out and recording of the second layer (L1). To realize such a high optical requirements, the dye and its distribution, groove shapes, and semi-reflective metal layer (usually silver alloy) are carefully optimized. Reflection of the second recording layer must be maximized to overcome the influence of the absorption and reflection of the first recording stack.

The transparent spacer layer is about 55 µm thick and serves to separate, both physically and optically, the two recording planes. At this separation the laser beam can easily be focused on either of the two layers by adjusting the position of the objective lens without noticeable disturbance coming from the light scattered in the other one. However, the spacer can substantially influence the quality of signals (tracking and HF). The most critical factor is coherent cross talk, which is caused by interference of light from in and out-of-focus layers, as well as effects of a (partially) written layer on the read out of and tracking the one behind (L1). These factors determine the boundary thickness values of the spacer to be between 45 µm and 70 µm.

	DVD+R DL Layer L0 & Layer 1	**DVD+R (single layer)**
Track pitch	0.74 µm	0.74 µm
Wobble period	4.672 µm	4.266 µm
Channel bit length	0.146 µm	0.133 µm
Reference velocity	3.84 m/s	3.49 m/s
Reflection	> 18 %	> 45 %
I14 modulation	≥ 0.60	≥ 0.60
I3/I14 modulation ratio	≥ 0.20	≥ 0.15
Data-to-clock jitter	< 9.0 %	< 9.0 %
Recording speed	2.4X	2.4X
Write power at 2.4X	< 30 mW	< 19 mW

Table 1. List of main physical parameters of the Dual Layer DVD+R optical media format (both layers are the same) and comparison with the normal DVD+R media specification.

The wobble addressing method is the same as in DVD+R/+RW and allows the same lossless linking accuracy as is obtained in both of these formats. The wobble period reflects the 10%

longer bit length of dual layer DVD media compared to single layer. The channel bit size of 146 nm is the same as in the DVD9 ROM pre-recorded disc, which was chosen to improve the system margins. The electrical signals determined for DVD+R DL meet the same requirements as those for its pre-recorded media predecessor. All these values were defined to ensure maximum compatibility with existing drives.

The DVD+R DL is recorded starting from the inside to outside of the first layer (L0). When the end of information recorded in L0 is reached, Middle Zone 0 is added. Next the drive focuses on the second recordable layer L1 to create a Middle Zone 1 that overlaps Middle Zone 0. The disc is then recorded from the outside rim inwards. The recording pattern corresponds to the opposite track path (OTP) only. Multi-session disc recording is foreseen as well as single session. It is not necessary to fill the entire disc with recorded data, but if one layer of DL disc has a recorded signal at a particular point on the disc, the other layer must have a matching signal, otherwise, a player may detect an error. This imposes some limitation on the data logistics on the disc.

The blank and recorded discs can be measured with the use of modified testing equipment based on the standard testers for Recordable DVD (see figure 3). The testing itself should follow the procedures already established for blank and recorded DVD+R type of media. Measuring the thickness of the spacer is a new, not fully explored, issue. It can be evaluated through measurements of the final disc's parameters or direct evaluation.

Layer 0 Layer 1

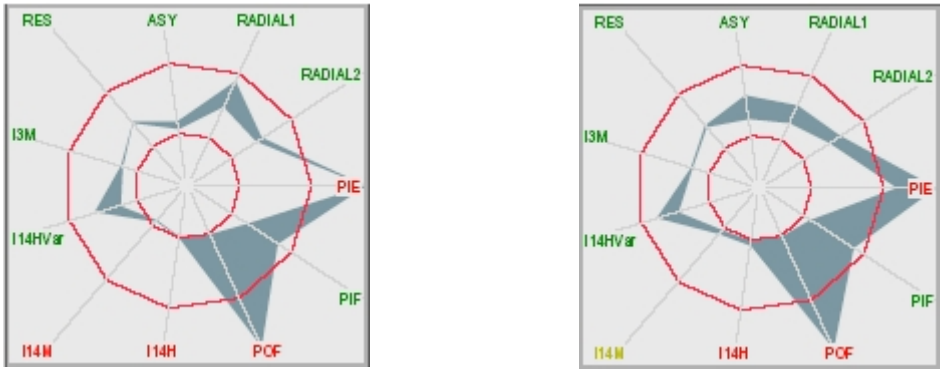

Figure.3. Example of a Quality Web Plot for both layers of a recorded DVD+R DL made during the development process. Some important media parameters are presented, such as modulations for short pits, long pits, Asymmetry, Radial noise, and digital errors. The red lines define the limits values for particular parameters. In this case the digital error rates (PIE, and POF) are out of specification. (Courtesy of DaTARIUS Group.)

Summary

Undoubtedly the new Dual Layer Recordable format opens new opportunities for consumers as well as media producers. It seems to be well defined; effectively targeting market needs, and supplementing the existing and popular pre-recorded optical media format – DVD-9. It gives consumers the benefit of storing up to 8.5 GB of data, or 4 hours of DVD quality video, or even 16 hours of VHS quality video. It seems to be a perfect supplement to the existing optical media formats, and should find plenty of applications.

DaTARIUS Corporate Information
DaTARIUS is a world-leading supplier of test equipment, not just proving but also improving optical media quality through comprehensive products and services embracing process optimization. Our Analyzers and Evaluators support all formats: pre-recorded, recordable, and rewritable, and our revolutionary DaTABANK technology is fully Blu-ray Disc (BD) and HD-DVD enabled. Complementing these testers: optimization, including our MF DisCo temperature regulator; and inspection, with print label, disc orientation and ident code validation. We also offer extensive training through our service and test centres worldwide. For the past 18 years DaTARIUS has been at the forefront of optical media technology with our commitment to the future of the industry and our customers.

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