MASTERING DVD-RAM

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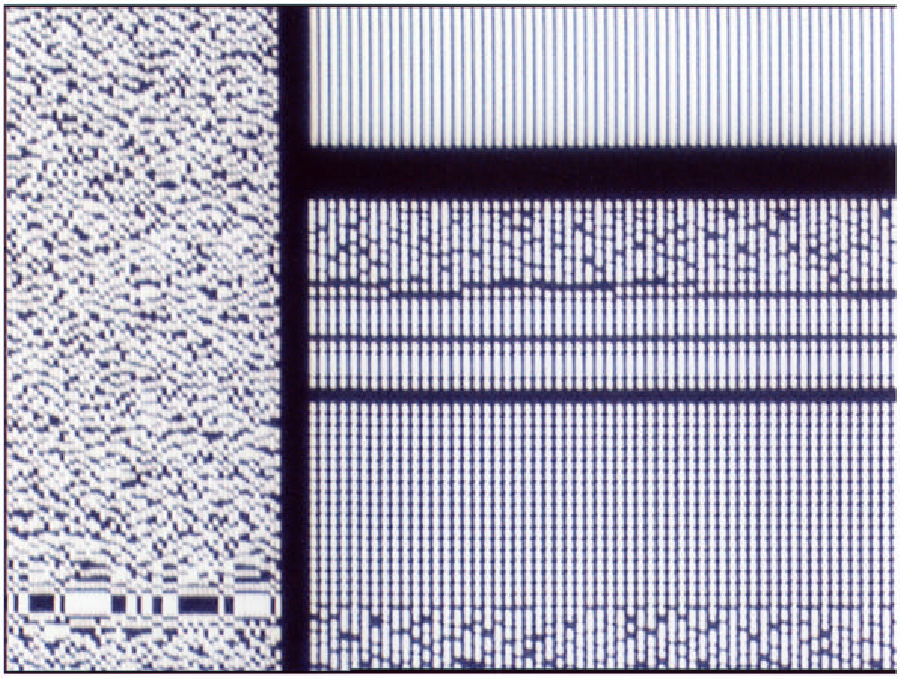
1. INTRODUCTION

The physical structure of DVD-RAM is complex and very different to previous re-writable formats. This complexity is the very thing which gives DVD-RAM its unsurpassed performance. It is the only member of the DVD family which is truly randomly re-writable. From the outset it supports double speed read and write. Its sectored format with headers and wobbled land and groove gives it excellent clock recovery and very high data integrity. This makes it a powerful and convenient computer peripheral and an excellent candidate for video recording with variable bit rate compression. In this paper we discuss the problems that are specific to mastering this format.



L62/132 DVD-RAM, TT SERVO IMPROVED, NEW RP CONTROL

2. CAV mastering

DVD-RAM is mastered in Constant Angular Velocity (CAV). The speed of the substrate under the objective lens changes with radius. This change in writing speed demands that the Recording Power (RP) is smoothly ramped with radius over a 2:1 range. This has to be subtly tuned because the relationship between writing speed and RP is not quite linear.

Our Laser Beam Recorder's translation mechanism and servo systems were first developed for CD in 1983. So it was optimised for Constant Linear Velocity (CLV) recording to give stepless changes in rotational and radial speed with radius. A CAV format like DVD-RAM demands that the headers are accurately aligned radially. There are two possibilities. Run the turntable at a constant RPM and synchronise the formatter to strobe pulses from the turntable encoder or slave the turntable to rotational clock signal generated by the formatter. In practice the mass of the turntable and substrate make for a better "phase lock loop" to follow constant crystal controlled clock pulses from the formatter. This is the method universally adopted. We term this Slaved CAV. In this way the rotational jitter easily meets the RAM specification for header alignment.

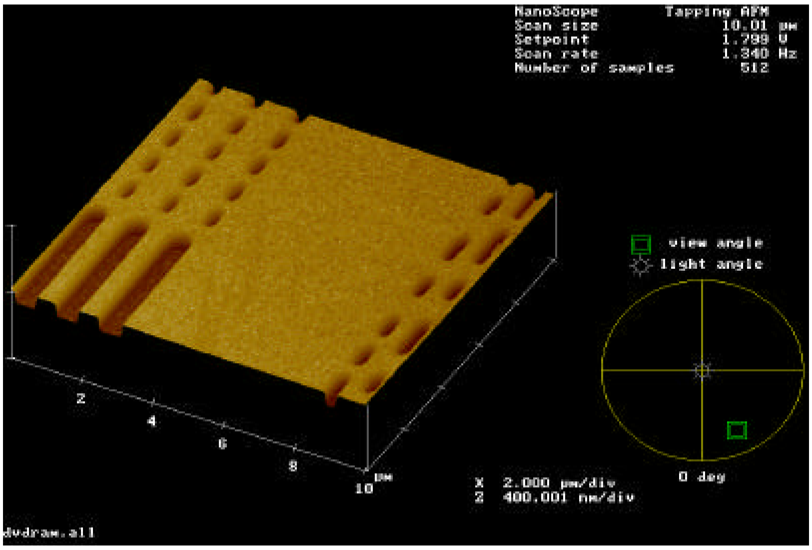
3. Formatters for DVD-RAM

However there is a further complication. To achieve the best jitter and asymetry (duty cycle) for the header pits there has to be a way to adjust the position or timing of the start and/or end of the pits. Simple enough so far and routinely applied to CD and DVD. But because RAM is mastered in CAV and the length of these pits along the track is constant with radius their angular length and timing varies with radius. So the Formatter has to be able to adjust this timing correction smoothly over a 2:1 range from ID to OD.

Unfortunately most commercially available formatters have insufficient range of adjustment to make headers with good jitter at the right asymetry. There are other subtler corrections that may be needed at the start and end of each zone that are not catered for at all.

4. The transition from 2.6 to 4.7 GB DVD-RAM

A very simple problem occurred in going from 2.6 to 4.7 GB. The track pitch of lead in and recordable area for 2.6 was constant at 740 nm. For 4.7 the lead in is still at 740 nm but the recordable area is at 680 nm. Commercial formatters of the time did not allow for the pitch change and could not be paused to allow the new track pitch to become stable. This was soon rectified. So now we write the lead in and measure the precise radius where it ends. The formatter then paused untill the new track pitch is stable and until the traverse reaches that radius plus 4 – 6 microns at which point writing the recordable area starts. Fortunately the LBR function to support this had been developed years earlier for speeding up the mastering of short CD's. It allowed the program area to be written at 1X (The fastest encoders could go at the time) and the lead out at some higher speed – hence High Speed Leadout. This required accurate control of the start of the HSL so that it could be "stitched" on within 2 to 3 microns.



5. Write strategies

There are two basic mastering strategies for DVD-RAM.

A. Use one beam to write lead in, headers and grooves.

Advantage. Only needs a single beam recorder

Disadvantage. Need very fast deflection to offset the headers and there is less flexibility to control feature width between embossed and groove areas.

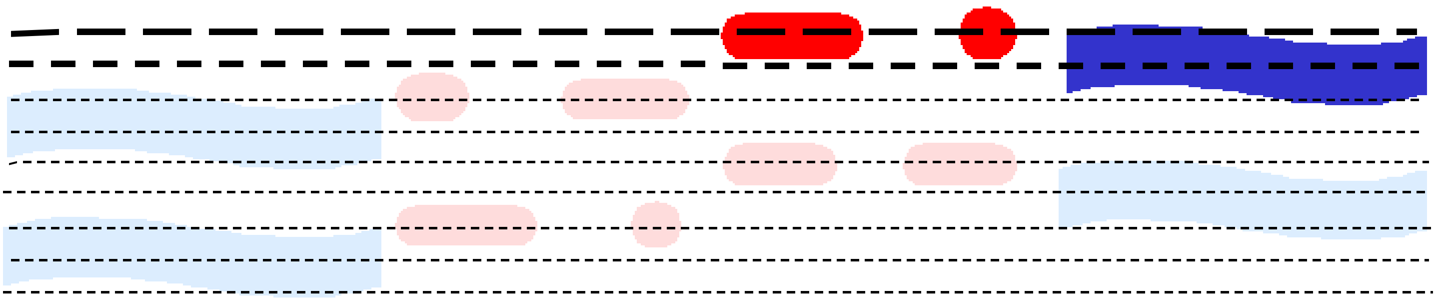
B. Use one beam to write lead in and headers and a second beam to write the grooves.

Advantage. Allows separate control of width of embossed features and grooves. Does not need very fast deflection.

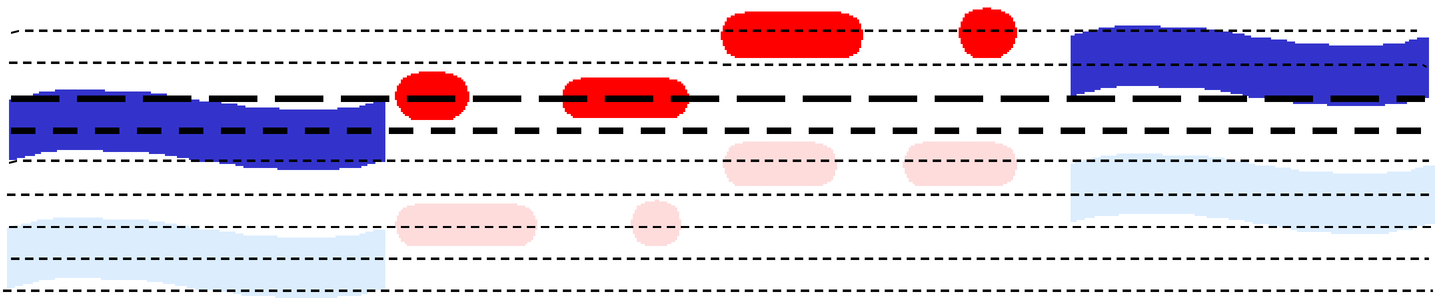
Disadvantage. Needs a Dual Beam Recorder (DBR).

We chose to use B with a dual beam recorder. In part because to support all DVD formats we needed a DBR. Also it looked like a more flexible way to do it. For example, the width of the lead and header pits need to be similar at ~ 300 nm – easy to achieve using a DVD spot. However the groove is much wider at ~ 680 nm, ideally made with a bigger spot. Achieving a 2:1 change in feature width just by changing RP is very difficult.

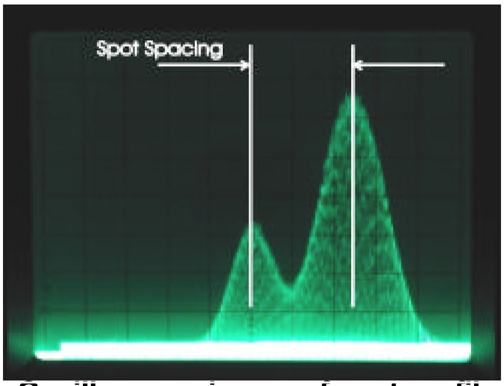
The headers are offset by half one track pitch from the centreline of the groove and land. There are two pairs of headers which are alternately offset by this amount inward and then outward. This allows the drive to know whether it is approaching a groove or a land. In practice we apply a half track pitch offset between the lead in / header spot and the groove spot. In this way no very fast deflection is needed. The groove is wobbled at 160kHz. Fortunately this does remain constant with radius. By using this constant offset between the two spots the headers and grooves can be written on successive revolutions. This is easiest to understand by looking at the following diagrams.



Pass one – outward deflected header and groove written
(Spots moving from left to right at transition from land to groove)



Pass two – inward deflected header and land written
(Spots moving from left to right at transition from groove to land)



Oscilloscope image of spot profile

UV Dual Beam Recorder

6. Focus control

To maintain precise focus of the spots on the substrate we use two focus systems. The first or primary focus servo uses a red laser diode and is active at all times. This allows the lens to be in the right place when the recording beams are off. A secondary focus system is included which uses light reflected back from the substrate to add more precision to the focus system. Now with a discontinuous format like DVD-RAM the light is off for most of the time. Two strategies had to be developed to solve this problem. The first is termed focus prediction. This stores the focus error signal for about one revolution. Using this stored signal tells the focus servo at what height the lens needs to be before it gets there. Added to this a "sample-servo" was developed which remembers where best focus was when the light went off and adds this to the stored focus prediction signal. When the light comes on again the servo is enabled to apply any small correction needed and to update the focus prediction's memory.

7. Control of feature geometry.

By using a DBR the recording power can be independently adjusted for lead in, headers, and groove. The proportion of the total light shared between the two beams is adjustable. There is an AOM before the beamsplitter to control the total light entering both beams and each beam path includes an AOM to modulate that beam and provide fine, dynamic power control. Power detectors are included before the beamsplitter and before the final objective.
By careful choice of which power detector controls which AOM appropriate control of embossed and groove features is possible. The spacing of the two spots on the substrate can also be controlled in both the DC sense and dynamically.

The wall angles of pits and grooves can be controlled by adjusting RP and developing time. Increasing RP increases feature width with little change in wall angle. Increasing developing time increases feature width but also increases wall angles. So by balancing these two parameters feature size and wall angle can be controlled. This is one of the great strengths of the photoresist process. But changes to developing time effect the whole master whereas changes to RP can be dynamic and control individual feature size.

However at ~ 70 nm groove depth the control over wall angle is limited. With these thin resist layers the maximum wall angle in practice is about 40 degrees. (At 150 – 200 nm 50 – 60 degrees is easily achieved).

8. Replication

We were able to take the process as far as moulding discs to see if we could replicate the geometry of the stamper. Much to our surprise our first attempts, using standard DVD pressing conditions made grooves only 15% of the depth of those on the stamper. The lead in and headers replicated well. By using higher mould temperatures and a slight increase in cycle time we were able to replicate 90% of the groove depth. This proved that they were mouldable but not that they would make good functional DVD-RAM's.

9. A complete process

Developing the mastering process for DVD-RAM cannot be done in isolation. All the flexibility can be built into the hardware and process to make headers and grooves of any dimension required. However the only tool to judge the result is an AFM. It can only confirm whether a particular paper specification has been met. This does not guarantee that the final product will be good. That is only possible in close collaboration between mastering and the downstream processes.

No mastering company can afford to install and run a complete DVD-RAM production line with its associated test equipment. That was one of the main reasons why Nimbus chose to partner with Unaxis. But even together we need input from the format developers to be able to provide the process support to ensure that our customers can make high quality media. Without this these formats will not have the manufacturing base to gain a useful market.