

AFM Analysis of HD-DVD Stampers

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Objective

- ◆ To demonstrate capability of mastering equipment for HD-DVD format
- ◆ To reveal “secrets” (bump geometry) of a specific mastering process that resulted in good playback.
- ◆ You should read this poster if you are interested in:
 - mastering and replicating BD, HD, other disc formats and other nano-patterns
 - automated image analysis and metrology

Mastering procedure

- ◆ Singulus Mastering LDM 3692 DUV recorder (257 nm laser), I-line resist
- ◆ Nominal signal (no write compensation)
- ◆ Laser Power was selected based on a power study
- ◆ Photoresist thickness was not optimized

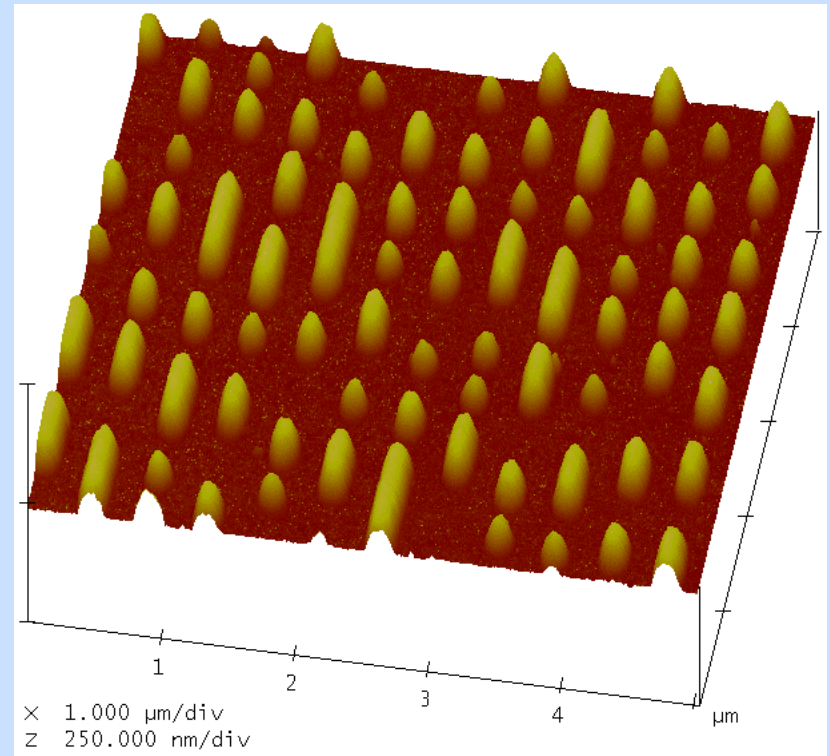
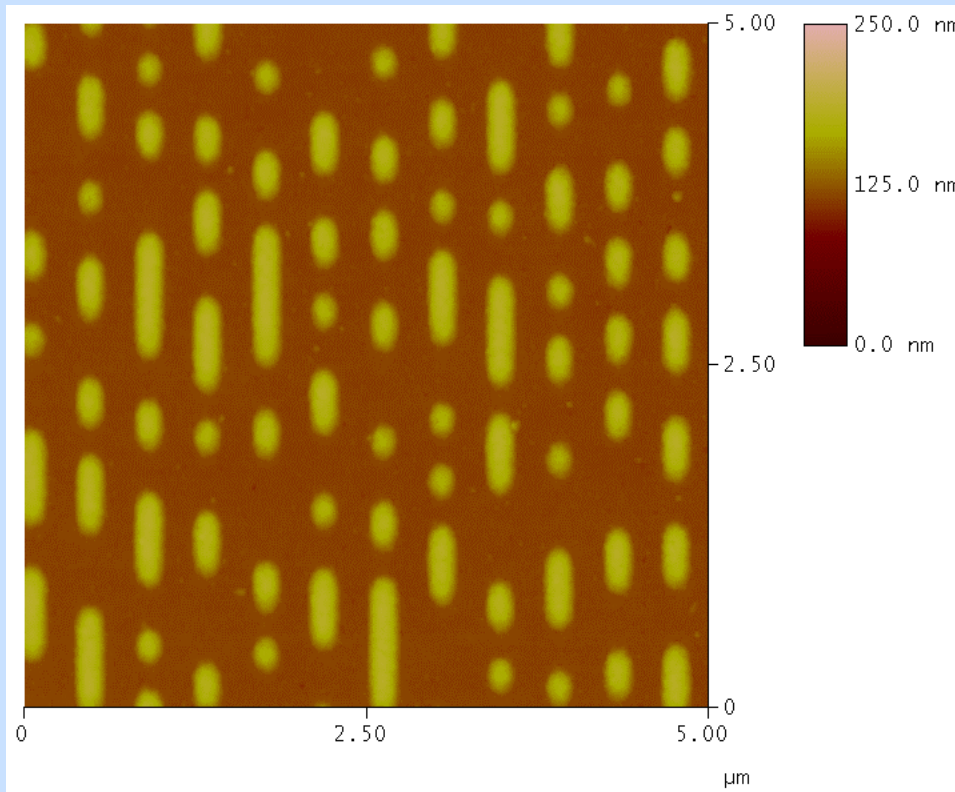
Electrical Properties of Finished Discs

Parameter	Measured	Specification
SbER (simulated bit error rate)	$5 * 10^{-9}$	$< 5 * 10^{-5}$
PRSNR (Partial Response Signal- to-Noise ratio, dB)	29	> 15
$2T_{asy}$ (2T-11T asymmetry)	-0.02	-0.10 to 0.10
$3T_{asy}$ (3T-11T asymmetry)	0.02	-0.10 to 0.10

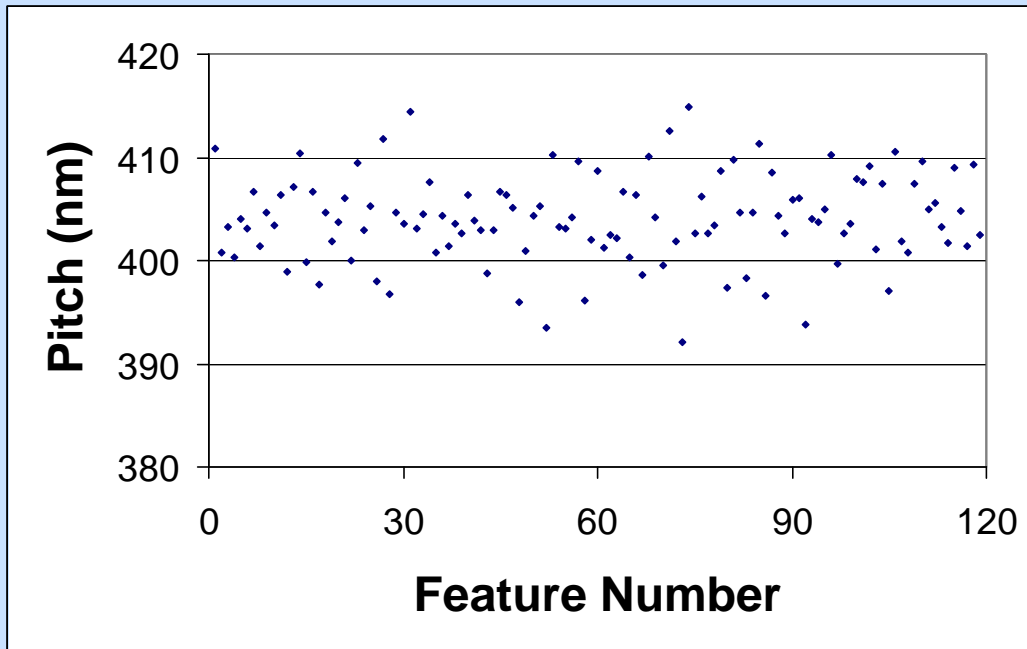
AFM Analysis

- ◆ NanoScope IIIA/Dimension 3100 AFM
- ◆ 6 5-um images of stamper at each spot (R=25 and 55mm)
- ◆ 292-nm pitch 2D calibration specimen
- ◆ DiscTrack Plus™ software

Images of HD-DVD Stamper



Pitch Variation



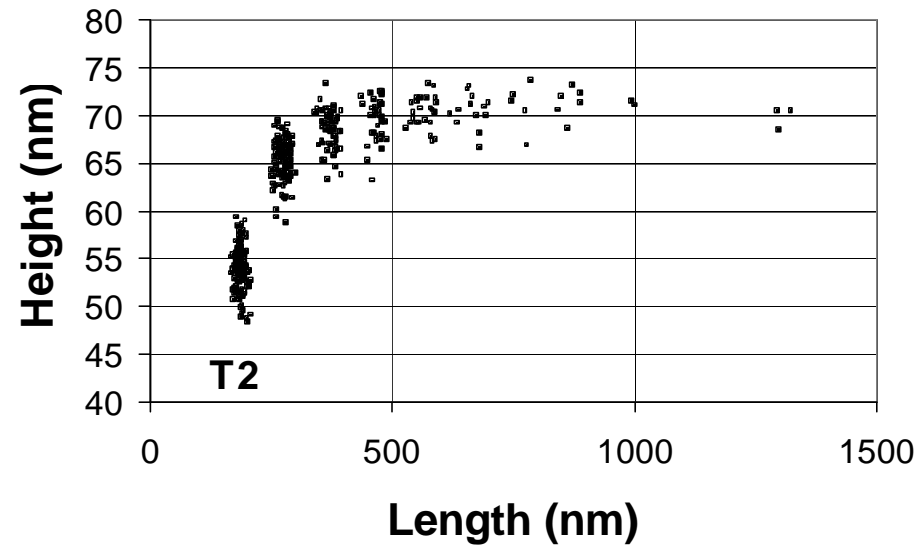
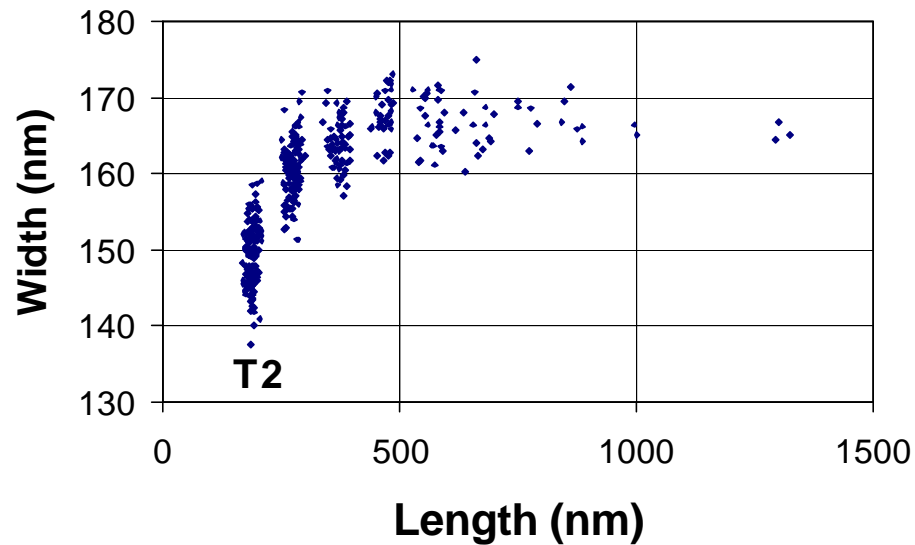
	Pitch (nm)
Mean	404.02
Standard Deviation	4.30
Range	22.94
N	119

Measured at radius 25 mm (features 1-61) and 55 mm (features 62-119).
The graph limits (380 to 420 nm) equal the specification limits. This stamper easily met the HD-DVD specification.

Bump Geometry Summary

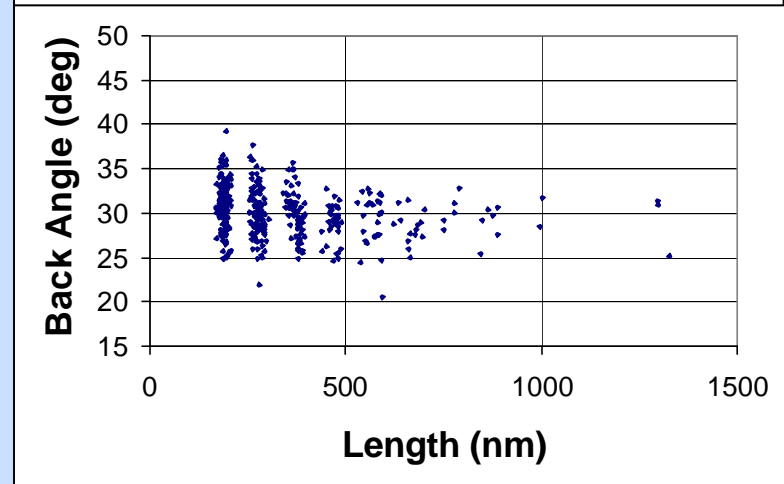
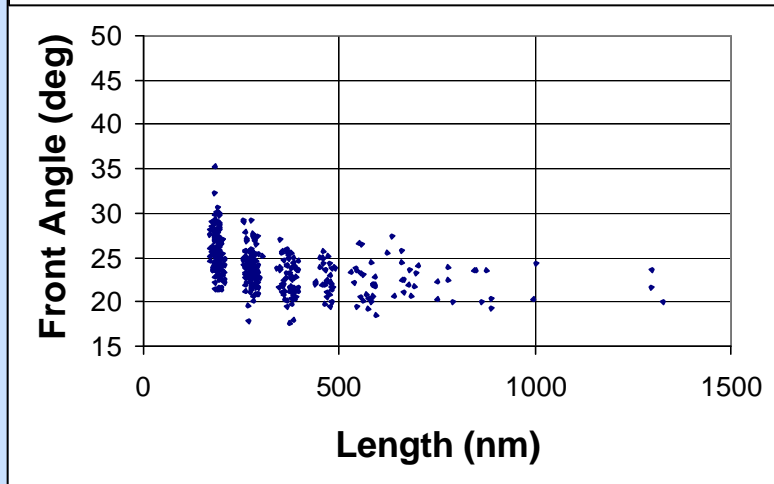
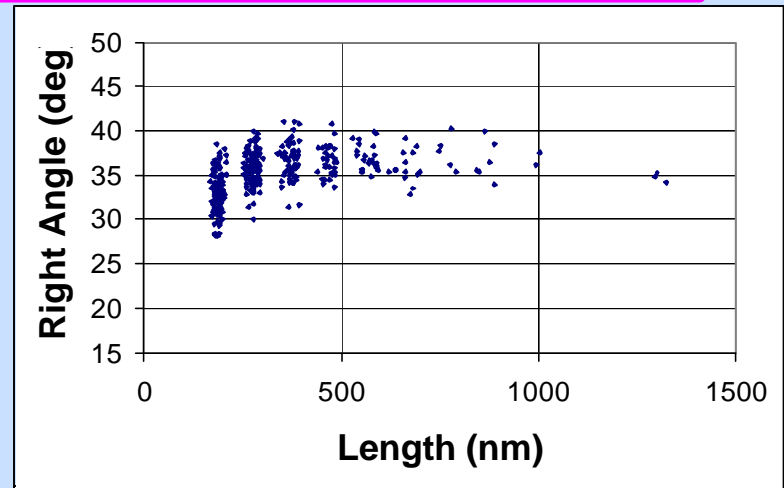
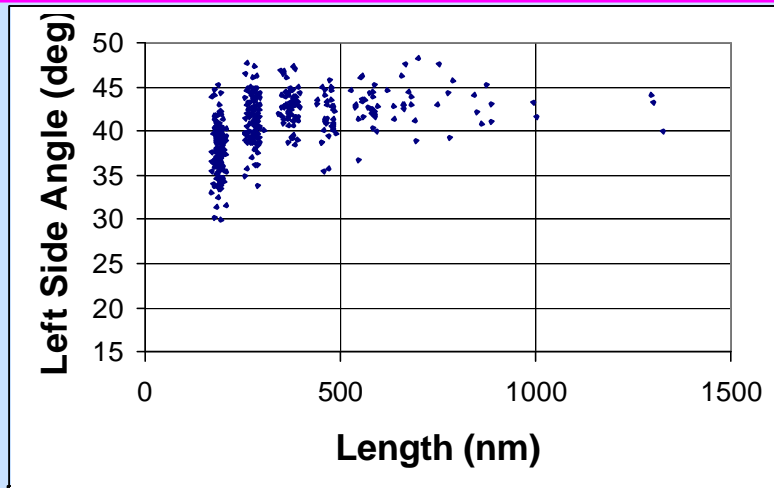
Width, Height and Side Wall Angles							
Data Set	Count	Mean	Standard Deviation	Standard Error of Mean	Maximum	Minimum	Range
Width (nm)							
R25	379	152.00	8.38	0.43	170.65	126.86	43.78
R55	390	158.67	8.12	0.41	174.87	137.47	37.40
Height across (nm)							
R25		59.87	6.81	0.35	70.90	47.60	23.30
R55		62.97	7.11	0.36	73.63	48.38	25.24
Left Side Angle (deg)							
R25		40.02	3.47	0.18	60.65	29.41	31.24
R55		40.63	3.32	0.17	48.28	29.91	18.38
Right Side Angle (deg)							
R25		34.86	2.57	0.13	45.44	27.45	17.99
R55		35.17	2.49	0.13	41.14	28.15	12.99
Back End Angle (deg)							
R25		29.76	2.90	0.15	42.79	17.23	25.56
R55		30.02	2.70	0.14	39.12	20.55	18.57
Front End Angle (deg)							
R25		23.58	2.66	0.14	35.04	16.56	18.47
R55		24.00	2.58	0.13	35.24	17.56	17.67

Width and Height varied with Length

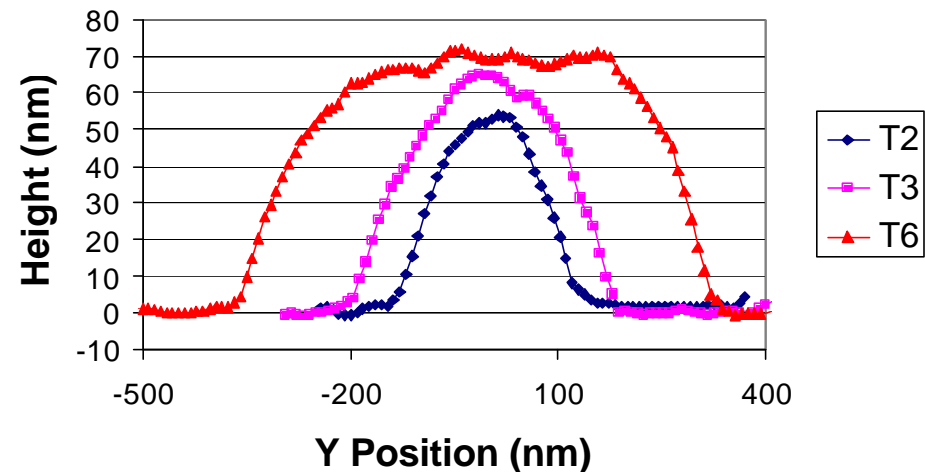
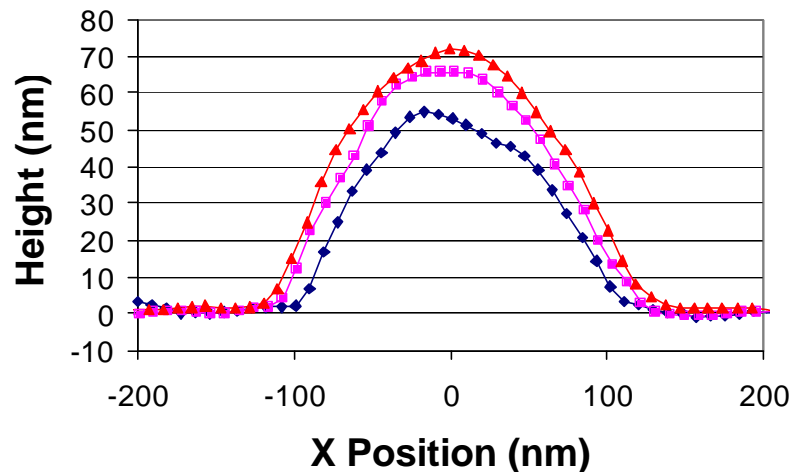


Data shown is for R=55 mm

Angles also varied with Length



A Closer Look: Height Profiles through center of Bumps

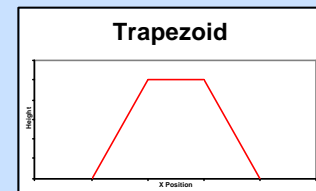


T2 and T3 were rounded in both across (X) and along (Y) the track.
T6 was rounded across and flat along the track.

Interpretation of Bump Shape and Comparison with DVD

Interpretation: T2 and T3 were not developed down to the glass. The centerline of T6 was developed down to the glass.

DVD bumps made by a photoresist process often have an ideal trapezoidal height profile.



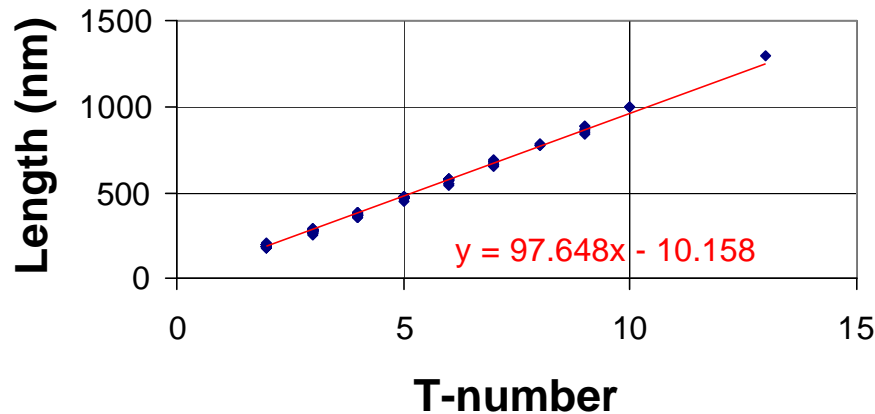
Therefore, if it were a DVD, we would classify the master as grossly underdeveloped. However, this geometry emerged as the one which gave best results on the replica, due to the characteristics of the equalizers defined for HD-DVD and of the detection scheme (PRML). We have not optimized pit depth and write strategy.

The rounded geometry surprised us.

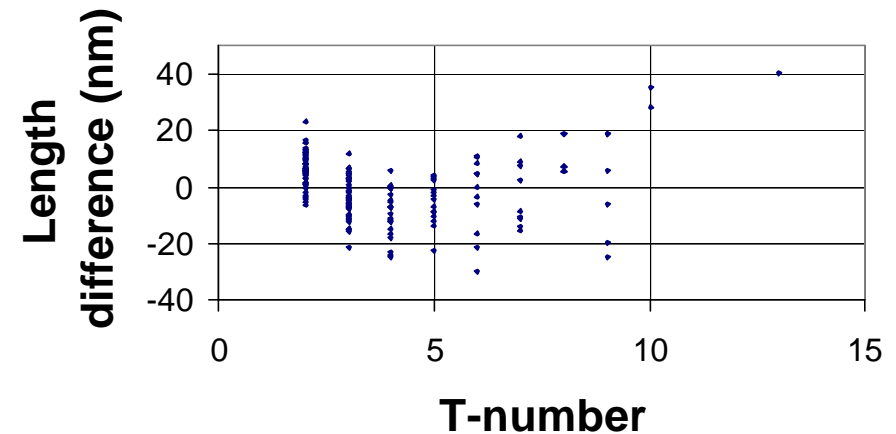
AFM Jitter:

Part 1 – Length Analysis

Bump Length vs. T-number



Residuals of Fit



Label each bump with its T-number.

Do Linear fit of Bump Length vs. T.

Slope (97.6 nm) is Channel Bit Length.

Intercept (-10.2 nm) is “Offset” (relates to write strategy and asymmetry).

AFM Jitter:

Part 2 – Within-Group S.D.

	Bump Length Analysis									
T	2	3	4	5	6	7	8	9	10	13
Count	58	42	24	15	11	9	3	6	2	1
Mean (nm)	191.63	279.12	371.81	472.73	572.19	670.81	781.37	867.41	997.94	1,299.38
Standard Deviation (nm)	5.78	7.20	8.41	7.52	13.69	11.96	7.04	18.76	5.09	
Total count of included groups		170								
Total SD within group (nm)		8.40								
JITTER:		6.08%								
				Channel Bit Length (nm)	97.65					
				Offset (nm)	-10.16					

$$AFMJitter = \left(\frac{SD_w}{\sqrt{2}} \right) \times \left(\frac{100}{CBL} \right)$$

from "AFM Length Analysis of Data Marks: Measuring Jitter, Asymmetry, Process Noise and Process Position", Donald A. Chernoff and David L. Burkhead, in Optical Data Storage 2001, Terril Hurst, Seiji Kobayashi, Editors, Proceedings of SPIE vol. 4342, pp. 515-523 (2002).

The within-group standard deviation ignores deviations of mean length from nominal or fit values and is a relatively pure measure of edge placement variation in mastering.

AFM Jitter Overview

<u>Jitter Analysis at R = 55 mm</u>		
	Bumps	Lands
AFM Jitter	6.08%	7.16%
Channel Bit Length:(nm)	97.65	100.70
Offset:(nm)	-10.16	26.27
Count:	170	106

Following are additional measures of stamper quality. As in the case of Jitter, smaller numbers are better.

<u>Within group standard deviations of size and shape parameters.</u>							
	Width (nm)	Height (nm)	Left Angle (degrees)	Right Angle (degrees)	Front Angle (degrees)	Back Angle (degrees)	
	3.82	2.10	2.60	1.98	2.11	2.52	

Interpretation of AFM Jitter for HD-DVD Stamper

HD-DVD uses PRML signal detection. Even though there is no jitter specification here, we believe these numbers give an indication of mastering quality by measuring the precision of edge placement. Whether the jitter values are also a good indication of playback quality remains to be investigated, by comparing data from discs with different playback quality. The use of some write compensation strategies to obtain best results in play back may very well spoil the AFM jitter.

Summary

- ◆ We produced HD-DVD stampers by a photoresist process and made replicas with good playback characteristics.
- ◆ AFM analysis showed that track pitch and pitch variation were in specification.
- ◆ Measurement of about 400 bumps showed size and shape variations with length, especially height and width.
- ◆ Cross-section profiles showed significant rounding, even for T6, indicating underdevelopment.
- ◆ Length classification and statistical analysis yielded “AFM Jitter” and other indicators of mastering quality.
- ◆ Next step: Modify the recording process so that the optimum read-out signals are acquired with pits that are well formed.

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- ◆ Second-hand AFMs
- ◆ Calibration specimens



Don Chernoff