Measuring Size, Shape and Position of Pits and Grooves

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Outline

- Why make Physical Measurements of Pits and Grooves?
- Pit Geometry and Jitter (DVD-ROM)
- Groove Geometry (CD-R)
- Track centering in complex headers (M-O)
- Wobble groove amplitude (DVD+RW, CD-R)
**DVD = NanoTechnology**

- Feature Size: 400 nm L x 320 nm W x 120 nm H
- Track Pitch: 740 nm
  Mean +/- 10
  Range 710-770
- Jitter: 8% = 11 nm
- Nanometer Manufacturing needs Nanometer Inspection Tools

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**Scanning Probe Microscope**
Atomic Force Microscope

Probes

- Batch fabricated using lithography and etching techniques
- Pyramid tips are extremely sharp: end radii 5-40 nm
- Cantilevers 50-500μm long
- Cantilever spring constants ~0.1 - 50 N/m
- Resonant frequencies 10 kHz - 1 MHz
DiscTrack Plus makes AFM more Powerful

- AFM = Atomic Force Microscope
- AFM gives 3-Dimensional Images of individual pits
- AFM is used at many Disc companies
- Root Cause Analysis
- Correlation of Dimensions

Plowing Marks ("clouds")
Process Optimization

- Indirect Control Using Disc Analyzer

Pit Geometry is a hidden variable

Process Optimization

- DiscTrack Plus provides missing link

Causes and Effects of Pit Geometry can now be Examined
Data Analysis

◆ Old Method
  – Built-in Tools

◆ New Method
  – Add-on Tools: DiscTrack Plus™
    – Patented

Old Method

◆ Height 149 nm
◆ Width 335 nm
◆ Pitch 1481/2
  = 740 nm
**Method Characteristics:**

<table>
<thead>
<tr>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick, easy for single measurements</td>
<td>Find Features Automatically</td>
</tr>
<tr>
<td>Imprecise (1 pixel)</td>
<td>Sub-Pixel Precision</td>
</tr>
<tr>
<td>Inaccurate (up to 5% error)</td>
<td>Detect, correct measurement errors (to 0.3% accuracy)</td>
</tr>
<tr>
<td>Slow, tedious for many measurements</td>
<td>Measure 100s of Features Easily</td>
</tr>
</tbody>
</table>

**Mental State vs. Measurement Number**

<table>
<thead>
<tr>
<th>Manual</th>
<th>Automatic</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Mental State" /></td>
<td><img src="image2.png" alt="Mental State" /></td>
</tr>
<tr>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>10000</td>
</tr>
<tr>
<td>10000</td>
<td>100000</td>
</tr>
</tbody>
</table>
Automated measurement without calibration correction

Automated measurement with calibration correction
Mean values of T3 width (Automated measurements)

Feature Geometry

Automated, high-accuracy measurement of size, shape, and position of individual features
Feature Geometry

Height Profile across a bump

Width Near Top

Width at user defined height

Width Near Bottom

Sidewall Angle

Height Profile:

- Height
- Position

Data Capture:
10 um Scans for DVD

Calibrator

Test (DVD Stamper)
Pit Geometry of DVD

Feature Width: Defect Identification
Feature detail

Expansion of Feature detail
Length Analysis gives “AFM Jitter” and more

<table>
<thead>
<tr>
<th>Length Analysis</th>
<th>Bumps</th>
<th>Lands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jitter</td>
<td>6.82%</td>
<td>6.00%</td>
</tr>
<tr>
<td>Channel bit length (nm)</td>
<td>134.38</td>
<td>133.68</td>
</tr>
<tr>
<td>Offset (nm)</td>
<td>31.88</td>
<td>-36.76</td>
</tr>
</tbody>
</table>

Good Stampers have Jitter about 3 - 3.5%

Length deviation vs T number (Power series stamper)
Write Strategy / Length Offset

Length vs. T Number

Length Analysis
(Write Strategy)

Slope = 133.51
(Channel Bit length)

Y intercept = -34.21 nm
(Length Offset)

Length offset vs relative laser power

Y intercept = -34.21 nm
(Length Offset)
Asymmetry vs Length Offset

![Graph showing Asymmetry vs Length Offset](image)

Comparison of DiscTrack Plus with Stamper Player

<table>
<thead>
<tr>
<th></th>
<th>Effect (Bump)</th>
<th>Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Laser Power</td>
<td>12.5% 0.0% -10.0%</td>
<td>12.5% 0.0% -10.0%</td>
</tr>
<tr>
<td>Jitter (%)</td>
<td>3.20% 3.29% 3.34%</td>
<td>3.00% 3.35% 3.54%</td>
</tr>
<tr>
<td>Channel Bit Length</td>
<td>132.94 133.05 132.63</td>
<td>132.66 133.26 135.05</td>
</tr>
<tr>
<td>Offset</td>
<td>-7.09 -37.61 -74.91</td>
<td>1.90 34.20 65.32</td>
</tr>
<tr>
<td>Mean Width at T3</td>
<td>322.27 299.13 259.80</td>
<td></td>
</tr>
<tr>
<td>Width Variation</td>
<td>9.61 7.29 7.30</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Stamper Player</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jitter (%)</td>
<td>10.10% 7.10% 15.20%</td>
</tr>
<tr>
<td>Asymmetry</td>
<td>17.90% 6.10% -5.90%</td>
</tr>
</tbody>
</table>
How do you fix a jitter problem?

Jitter

- Edge Placement Variation
- Asymmetry
- Length Bias
- Other effects

Jitter comes from:

- Length Offset (Deviation)
- Channel Bit Length
- Pit Geometry
- Track Pitch

Disc Analyzers give you a number

DiscTrack Plus Tells you what causes it

Image of CD-R Stamper
Summary of Measurements

Individual Width Measurements
Width of stamper ridges

Height of Stamper Ridges
OD angle in stamper ridges

ID angle in stamper ridges
Geometry of pre-formed groove in CD-R

<table>
<thead>
<tr>
<th>Mean values</th>
<th>Brand A</th>
<th>Brand B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groove Depth (nm)</td>
<td>135.61</td>
<td>172.18</td>
</tr>
<tr>
<td>Width at Half-Ht. (nm)</td>
<td>442.82</td>
<td>569.49</td>
</tr>
<tr>
<td>Left Side Angle (deg) (Outer Diameter Direction)</td>
<td>26.37</td>
<td>26.91</td>
</tr>
<tr>
<td>Right Side Angle (deg) (Inner Diameter Direction)</td>
<td>21.85</td>
<td>24.5</td>
</tr>
</tbody>
</table>

Complex Header Structure: Magneto Optical Disc

- Are the Pits Centered between the Grooves?
Track Pitch measurement of Magneto Optical disc

Pitch results for Groups A and B (left and right half tracks)

- Groups A and B had different Pitch, so Pits not centered between grooves
- Group A pitch had 5x less variation than Group B pitch, so Group A corresponds to 2 beams locked together. Group B pitch variation reflects stage motion in LBR.

<table>
<thead>
<tr>
<th>Half Tracks</th>
<th>Mean (nm)</th>
<th>StDev</th>
<th>Max</th>
<th>Min</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>B</td>
<td>622.98</td>
<td>10.61</td>
<td>631.37</td>
<td>601.02</td>
</tr>
<tr>
<td>Right</td>
<td>A</td>
<td>547.45</td>
<td>2.14</td>
<td>551.01</td>
<td>544.83</td>
</tr>
</tbody>
</table>
**Measurement of Groove Wobble Amplitude**

- Direct Physical Measurement using many, high-precision track pitch measurements
- Can Measure stampers or masters before replication
- Independent check on electrical testers
Pitch Measurements

Measure 50 pitch values along each pair of tracks.

Wobble Measurements

DVD+RW Wobble

<table>
<thead>
<tr>
<th>Track Number</th>
<th>Pitch (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>746.35</td>
</tr>
<tr>
<td>2</td>
<td>746.35</td>
</tr>
<tr>
<td>3</td>
<td>735.35</td>
</tr>
<tr>
<td>4</td>
<td>724.35</td>
</tr>
<tr>
<td>5</td>
<td>713.35</td>
</tr>
<tr>
<td>6</td>
<td>702.35</td>
</tr>
<tr>
<td>7</td>
<td>691.35</td>
</tr>
<tr>
<td>8</td>
<td>680.35</td>
</tr>
<tr>
<td>9</td>
<td>669.35</td>
</tr>
<tr>
<td>10</td>
<td>658.35</td>
</tr>
<tr>
<td>11</td>
<td>647.35</td>
</tr>
<tr>
<td>12</td>
<td>636.35</td>
</tr>
</tbody>
</table>

Pitch (nm)
- Mean: 746.35
- Range: 114.37
- Wobble Amplitude: 28.59
Compute Wobble from Track Pitch

Wobble in adjacent tracks

Typical Measurement region

Mean Pitch (P)

Difference

4A

P-2A

P+2A

Track one

Wobble Amplitude (A)

Wobble amplitude greatly exaggerated

Track two

Wobble Measurement Sample Results

Wobble as measured in track pitch

Range: 136 nm
Wobble: 34 nm

Pitch (nm)

1 2 3 4 5 6 7 8 9 10 11 12

Track #
Summary

- AFM plus Automatic Tools
- Improved Calibration & Precision
- High Count --> Statistical Analysis
  - Track Pitch
  - Pit Geometry
  - Width Variation
  - Defects
  - Wobble

Advanced Surface Microscopy

- We don’t make the AFM, we make the AFM better.
- DiscTrack Plus™ Media Measurement System
- www.asmicro.com
- donc@asmicro.com
Where is ASM?

![Map of the United States with a highlighted area around Chicago and Indianapolis with a note indicating a 800 km radius circle covering half of the USA population.]

What does ASM do?

- Analytical Service Lab specializing in SPM (Scanning Probe Microscopy)
- Precision measurement systems and other software enhancements for SPM’s
- Buy and sell used NanoScopes
- Consulting and training in SPM