Complete Metrology Solutions
Imprint Technology

Templates, DTR and BPM Media

Simultaneous and Non-Destructive Measurements of

- **Depth**
- **Top and Bottom CD**
- **Residual Layer Thickness, RLT**
- **DLC Thickness**
- **Side Wall Angles**

Iris Bloomer
n&k Technology

March 2009

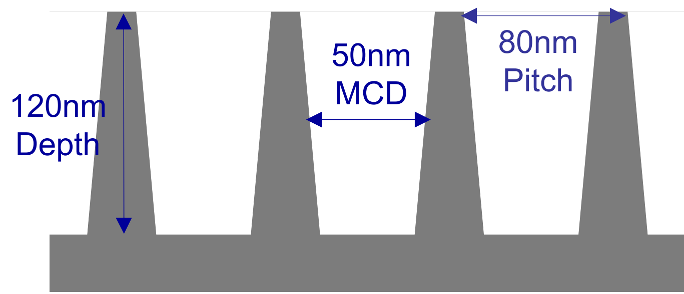
n&k Technology, Inc.

Outline

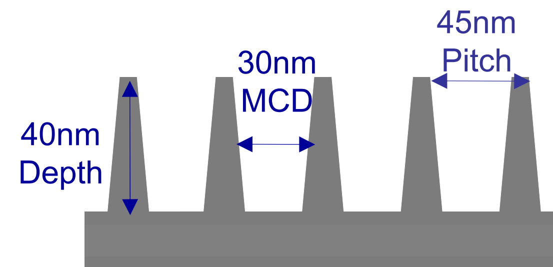
- The Challenge of Measuring Imprint Templates, DTR and BPM Media
- Surmounting this Challenge
- The n&k Gemini
- Some Measurement Examples
  - E-Beam Template
  - Template and Corresponding DTR Sample
  - BPM Media Sample
- Summary

n&k Technology, Inc.

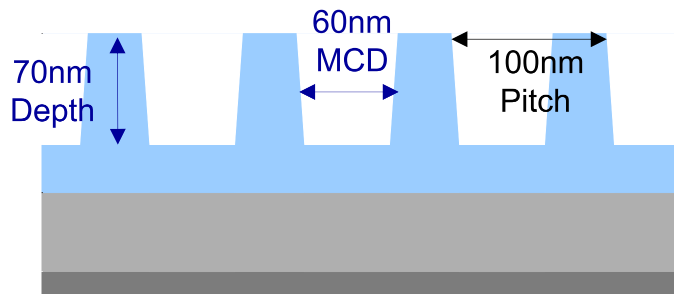
The Challenge



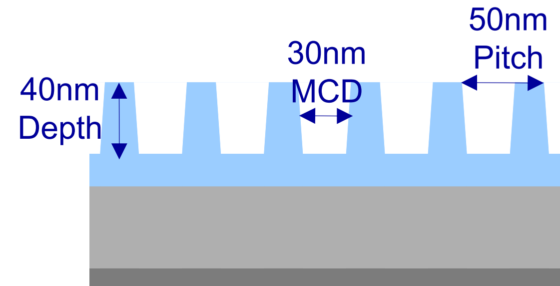
Current Generation Template



Next Generation Template



Current Generation Imprint



Next Generation Imprint

n&k Technology, Inc.

Sensitivity

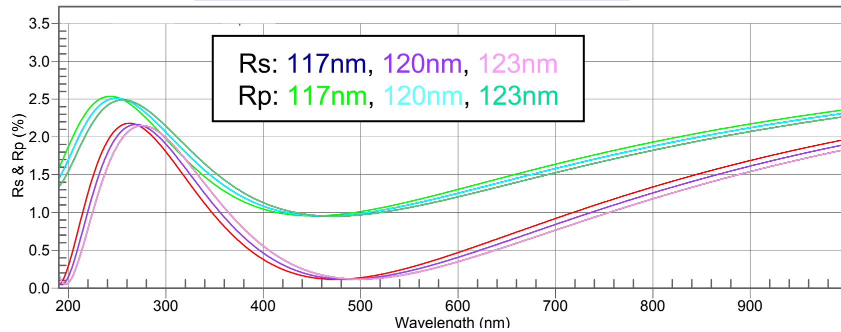
- Changes in parameters of interest produce only a very small change in the measured data
- Changes in measured data caused by variations of parameters of interest can occur anywhere in the measured spectrum, from the deep UV to the NIR
- The challenge corresponds to adequate **sensitivity** of the metrology tool

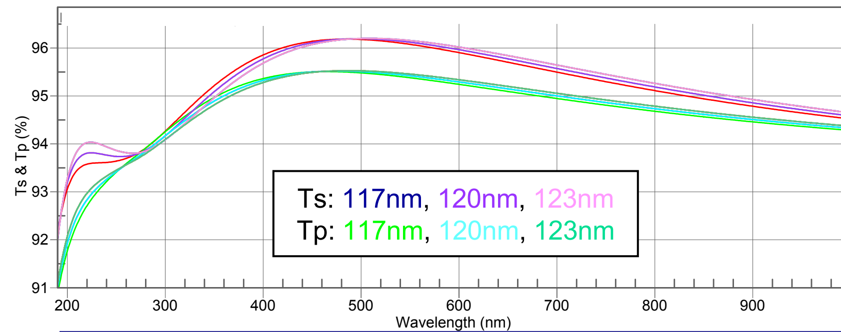
n&k Technology, Inc.

Change in Template Depth by a Few nm, ⇒ Change in Measured Data by a Fraction of a Per Cent

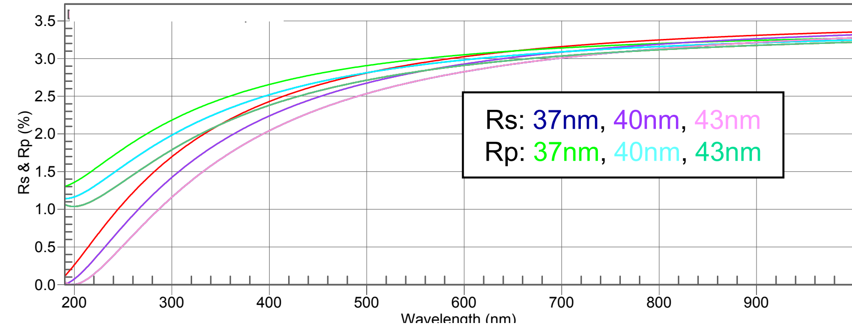
Quartz Depth Simulations for Nominal Value +/- 3nm

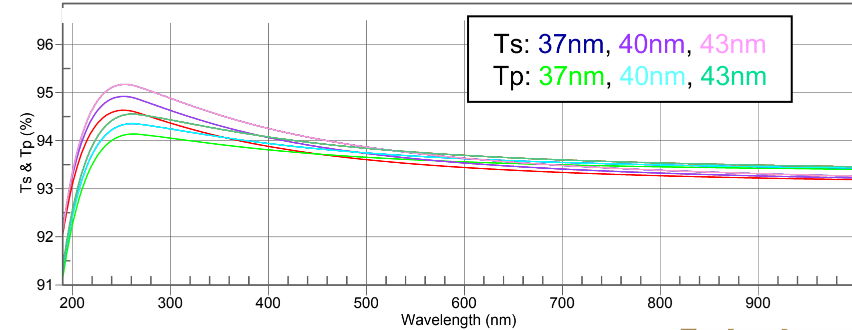
Current Template Type





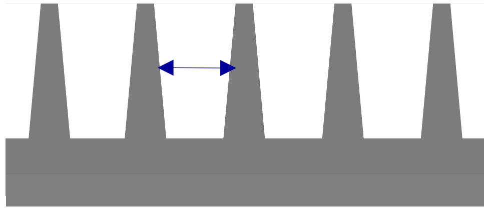
Next Generation Type





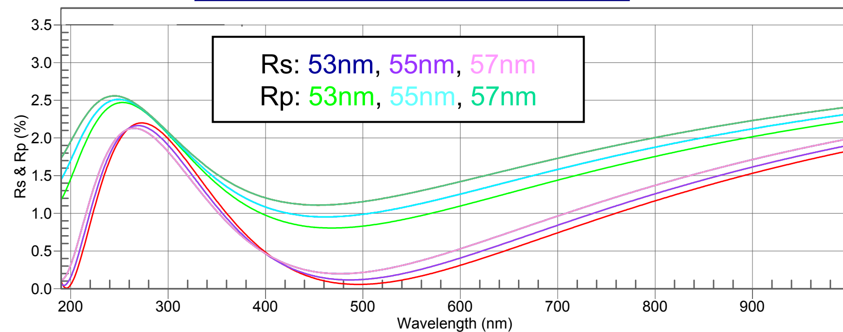
Technology, Inc.

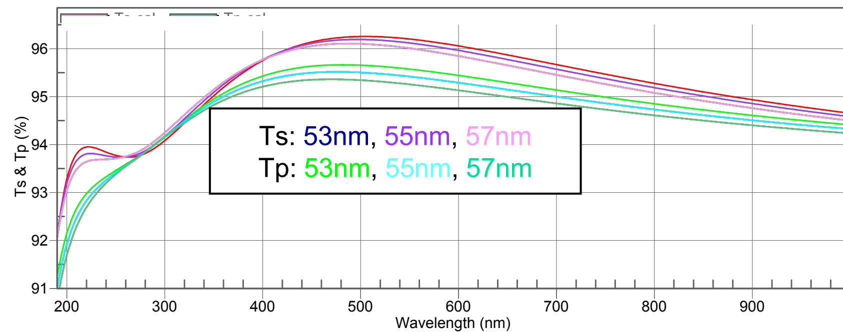
Change in Template MCD by a Few nm,
⇒ Change in Measured Data by a Fraction of a Per Cent



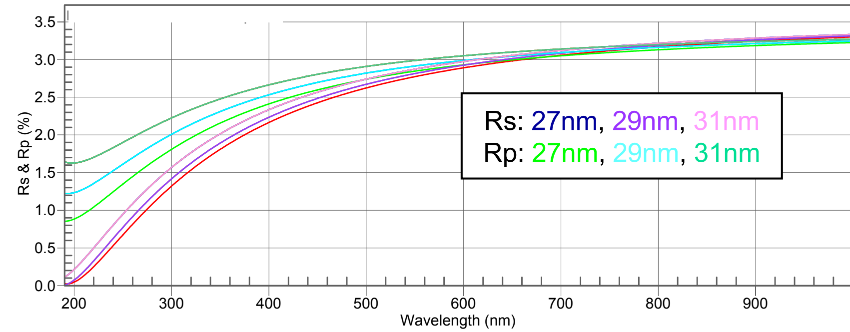
Middle CD Simulations for Nominal Value +/- 2nm

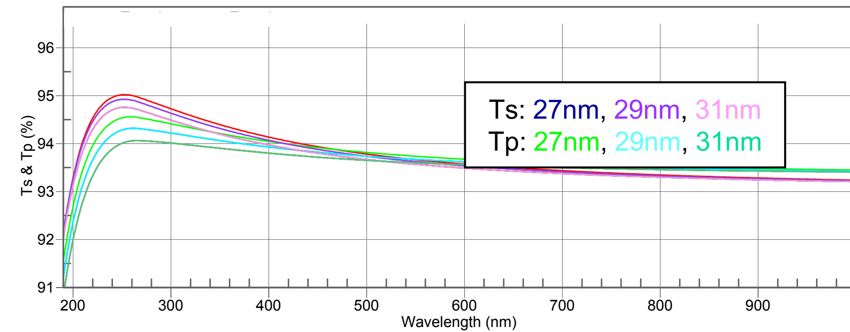
Current Template Type





Next Generation Type





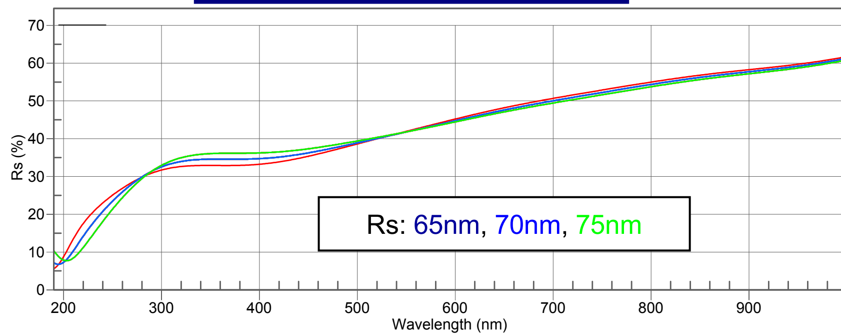
Technology, Inc.

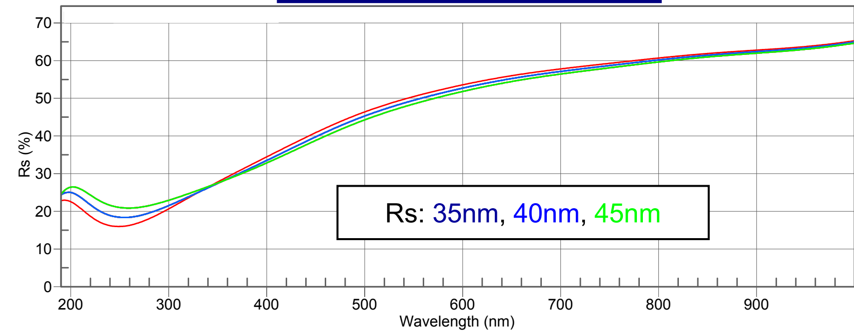
Change in Imprint Depth by a Few nm,
⇒ Change in Measured Data by a Fraction of a Per Cent

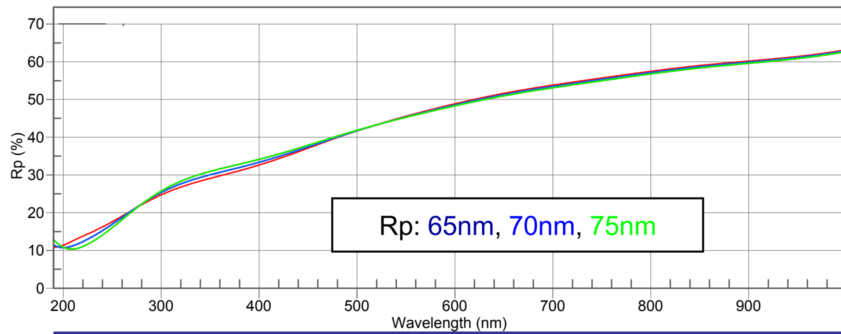
Grating Height Simulations for Nominal Value +/- 5nm

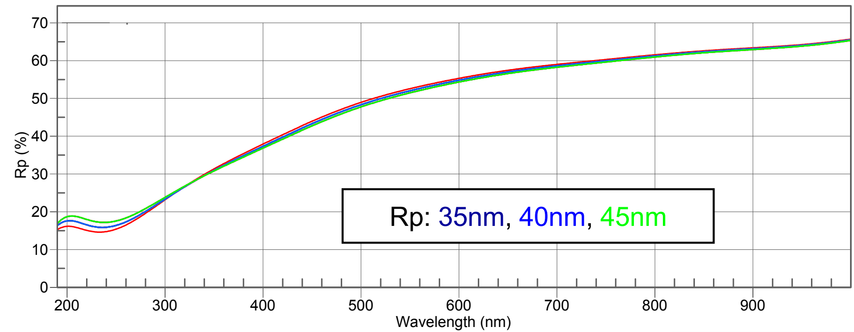
Current Imprint Type

Next Generation Type

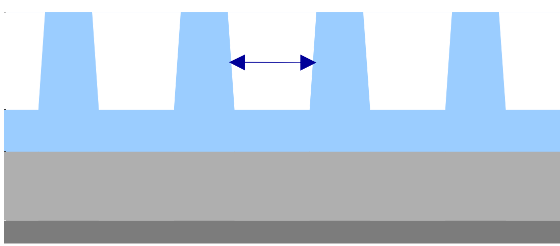








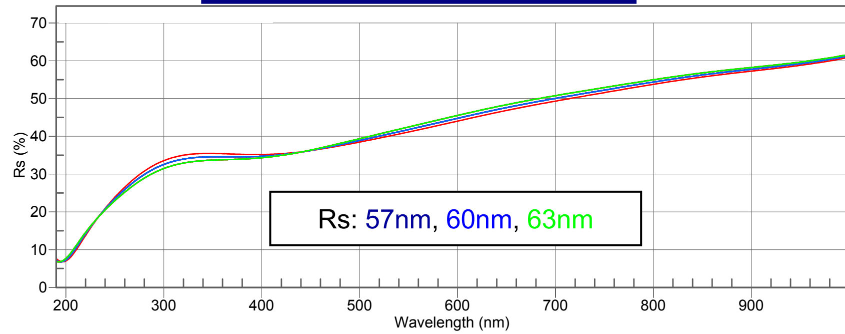
Change in Imprint MCD by a Few nm,
⇒ Change in Measured Data by a Fraction of a Per Cent

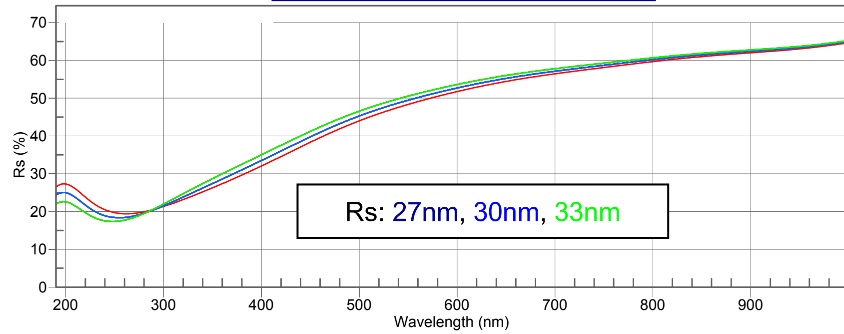


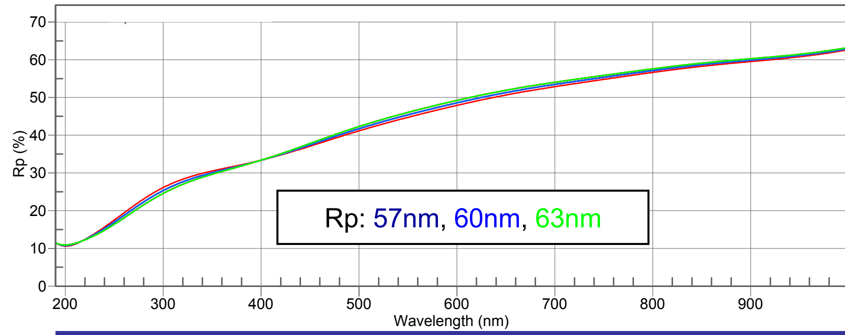
Middle CD Simulations for Nominal Value +/- 3nm

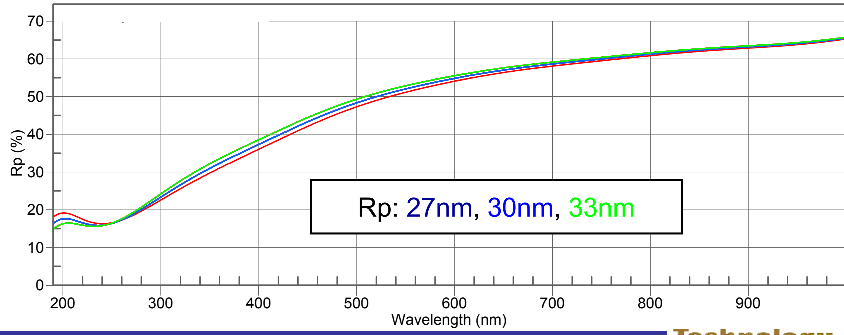
Current Imprint Type

Next Generation Type







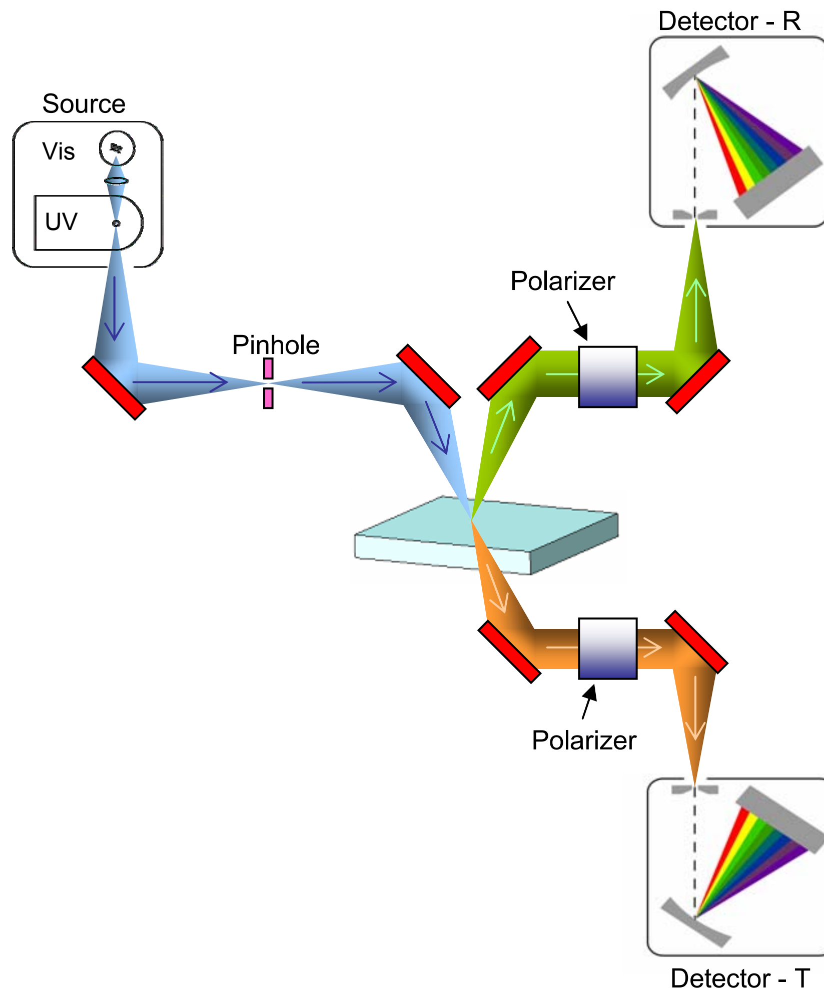


Achieving Measurement Sensitivity

- Optimized Signal to Noise
  - Necessary in order to distinguish changes in measured data due to changes in parameters (e.g. depth or CD) from noise in measured data
- Wavelength Range
  - Large wavelength range that includes DUV data is critical
  - Changes in parameters can cause changes anywhere in the DUV to NIR wavelength range
- Transmittance Measurements + Reflectance Needed for Templates
  - *T* provides greater sensitivity than *R* for Templates
  - Measured reflectance ≈ A few % for Templates
  - Measured transmittance > 90 % for Templates
    - Intensity of T >> Intensity of R,
    - ∴ more photons reach detector
    - The greater # of photons detected, the greater the signal
- Valid Physical Model for Analysis of Raw Data
  - Software must converge and overcome ambiguities in results
- Sample Handling for Disks
  - X-Y Stage not adequate for aligning gratings
  - X-Y-Z-θ is necessary

n&k Technology, Inc.

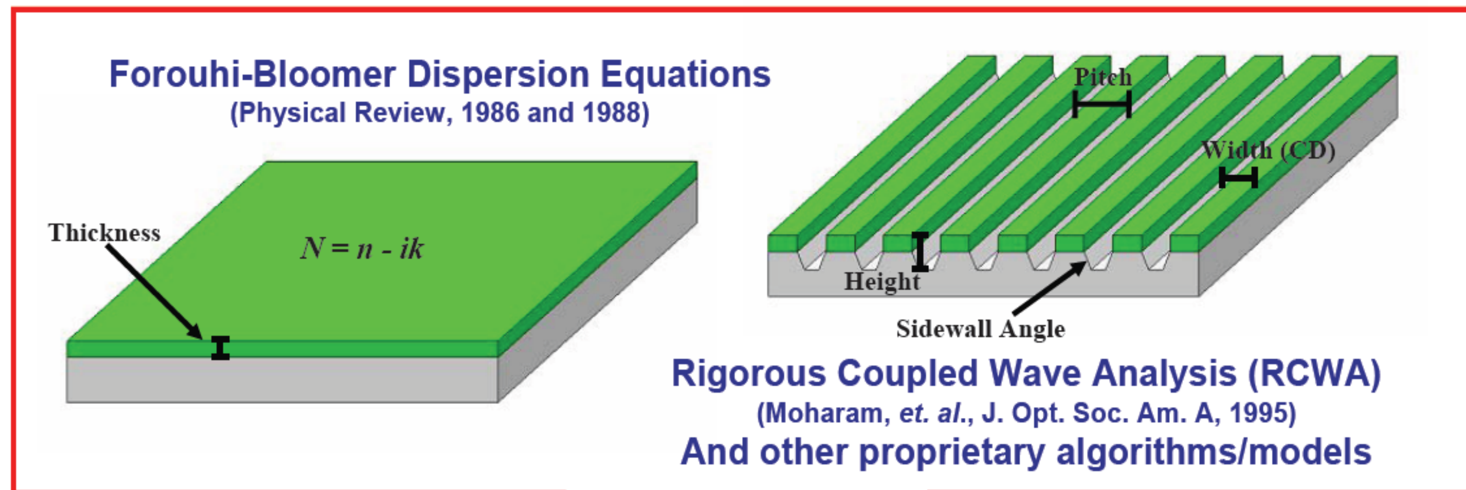
The n&k Gemini Optical Configuration Results in Optimized Signal to Noise



- Patented all-reflective optical design, **without** beam splitters and refractive lenses
- Optimized polarized *R* and *T* data over the entire wavelength range DUV-VIS-NIR
- 190 – 1000 nm spectrum in 1 nm intervals
- Measurement Spot
  - **Reflectance: 50 µm**
  - **Transmittance: 50 µm**
- Measurement Time: 1 s/pt

n&k Technology, Inc.

The n&k Gemini Valid Physical Model



Hybrid RCWA

Forouhi-Bloomer Model Combined with RCWA is Used for Analysis

n&k Technology, Inc.

The n&k Gemini

Provides Sufficient Sensitivity for Measurements of Templates, DTR and BPM Media

- Incorporates optical design for optimized signal to noise and wide wavelength range (190 – 1000 nm)
- Analysis based on Hybrid RCWA
- Fully Automated
- Polarized Reflectance (*Rs* and *Rp*)
  - Polarized Transmittance (*Ts* and *Tp*)
    - *Rs*, *Rp*, *Ts*, *Tp* simultaneously measured at the same point
  - Wavelength Range from 190 -1000 nm
- *Spot Size:*

  50 μm for Reflectance, 50 μm for Transmittance
- Automated X-Y-Z-θ Stage and Robot are designed to accommodate various size disks
  - Automatically aligns gratings to increase speed and reduce user error.

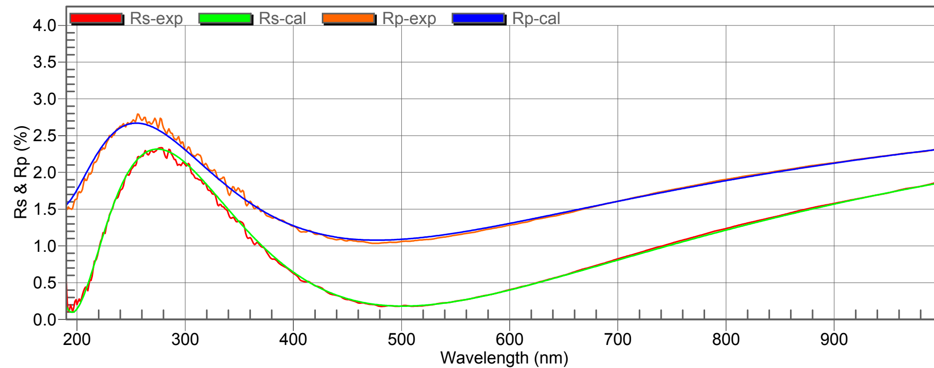
Engine of the n&k Gemini

n&k Technology, Inc.

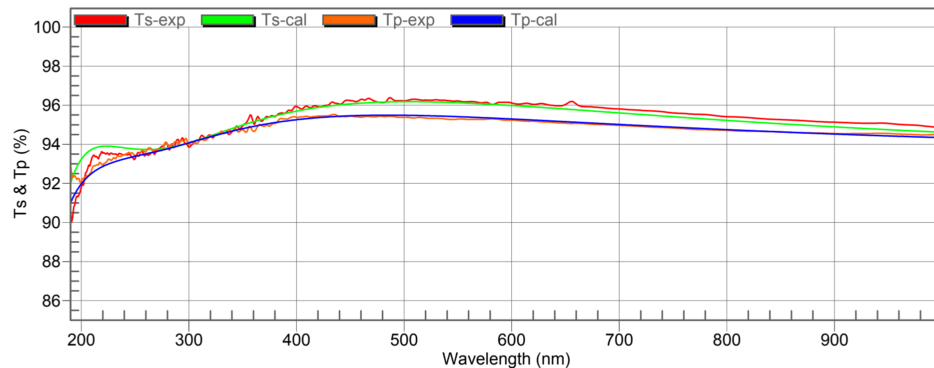
E-Beam Template Measurement

- 65mm square Sample, 0.25” thick
- Grating pattern at sample center
- Trenches in quartz, 80nm pitch

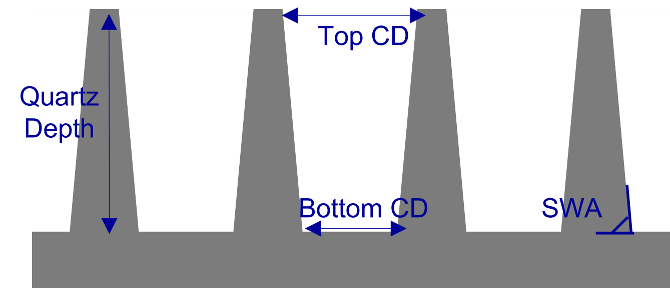
n&k Model and Typical Fit



Experimental and Calculated Reflectance (*Rs*, *Rp*)



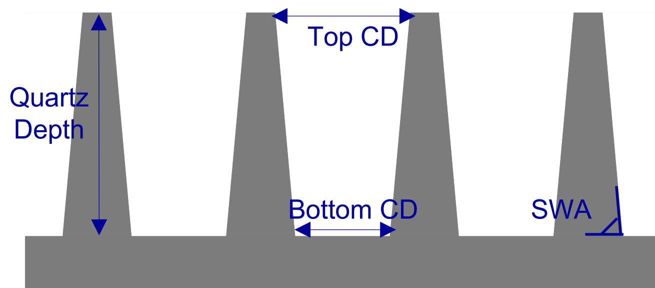
Experimental and Calculated Transmittance (*Ts*, *Tp*)



n&k Model

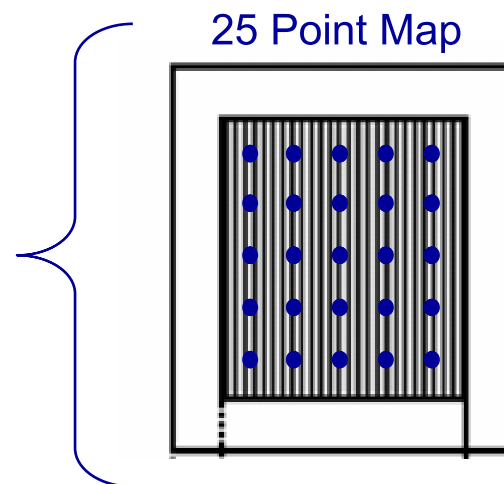
n&k Technology, Inc.

Parameters Simultaneously Measured and Mapped



- Quartz Depth
  - Mean = 1226.9Å, STD = 1.72
- Top CD
  - Mean 67.20nm, STD = 0.19
- Bottom CD
  - Mean 45.32nm, STD = 0.24
- Sidewall Angle
  - Mean 86.3º, STD = 0.025º

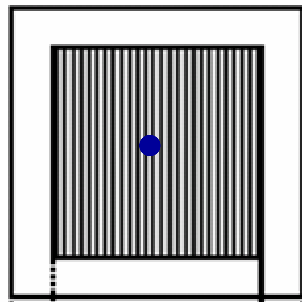
25 Point Map

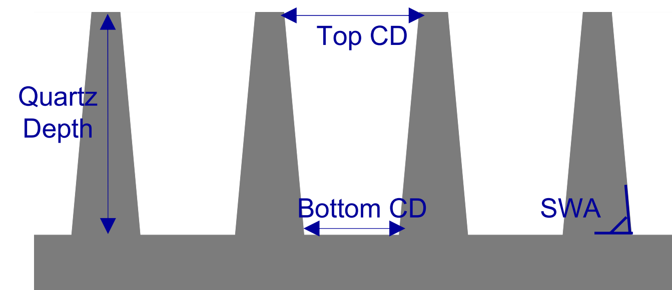


n&k Technology, Inc.

Repeatability Results

Center point measured
30 times consecutively



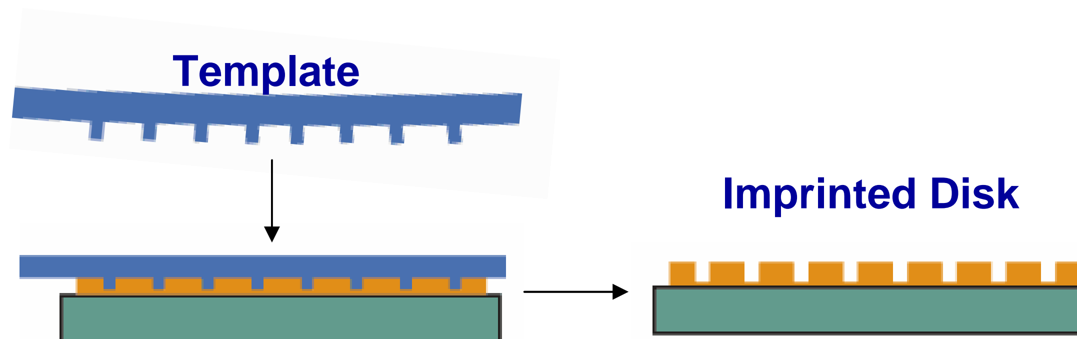


	Mean Value	Std Dev (1σ)
Quartz Depth	1226.8Å	0.43Å
Top CD	67.41nm	0.074nm
Bottom CD	45.02nm	0.146nm
Sidewall Angle	86.2°	0.021°

n&k Technology, Inc.

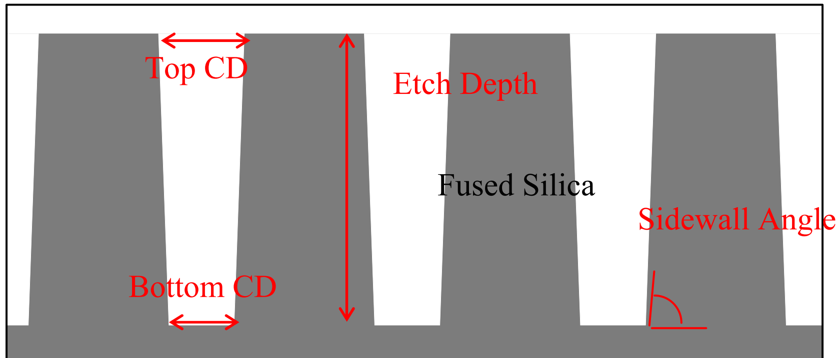
Template and Corresponding Imprint Measurement

- Measurements of Template and DTR disk made using the same Template
- Depth, and CD results of the Template and the DTR disk are compared

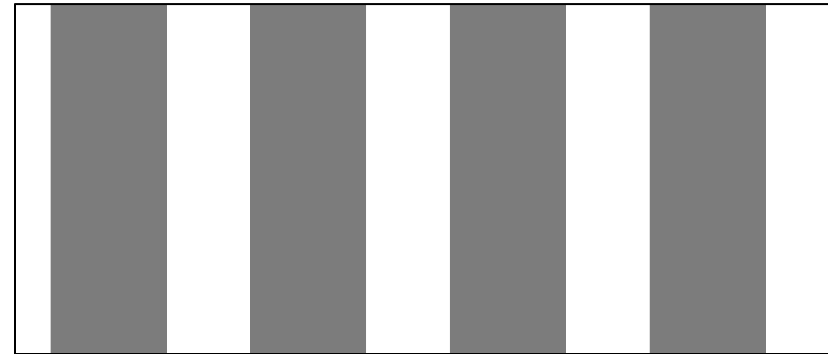


n&k Technology, Inc.

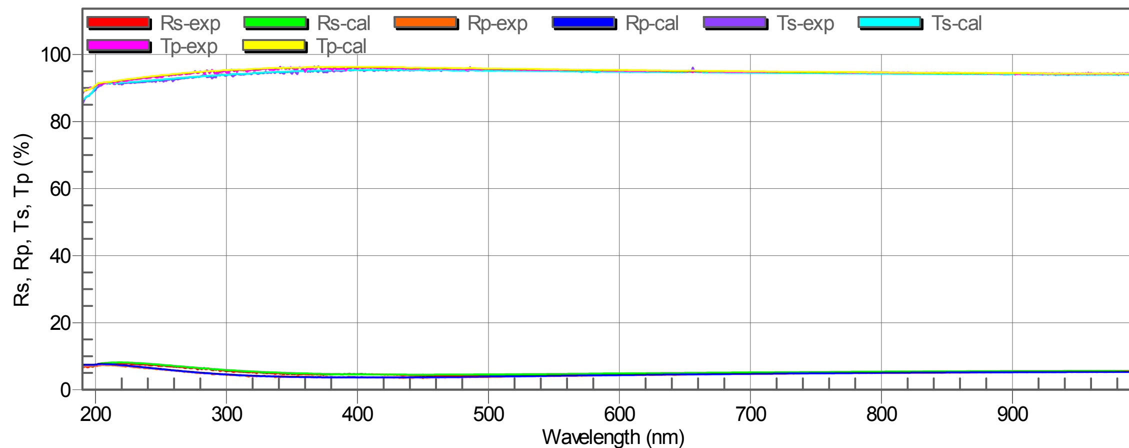
Template and Corresponding Imprint Measurement
Template Model and Data Fit



Cross Section



Top-Down, Pitch=120nm

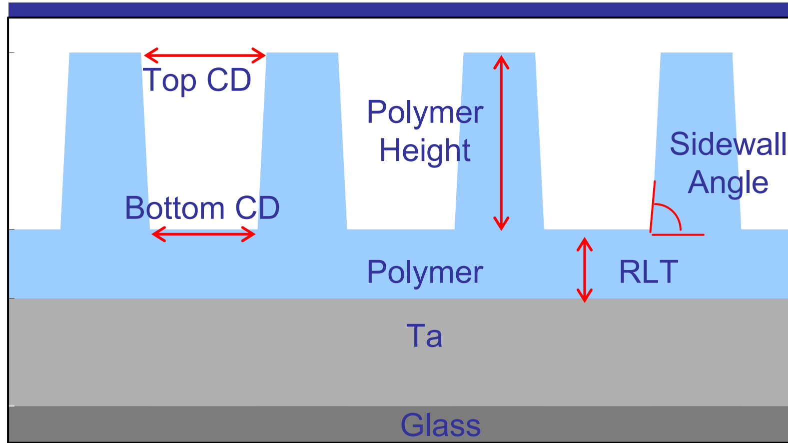


Typical Analysis Fit

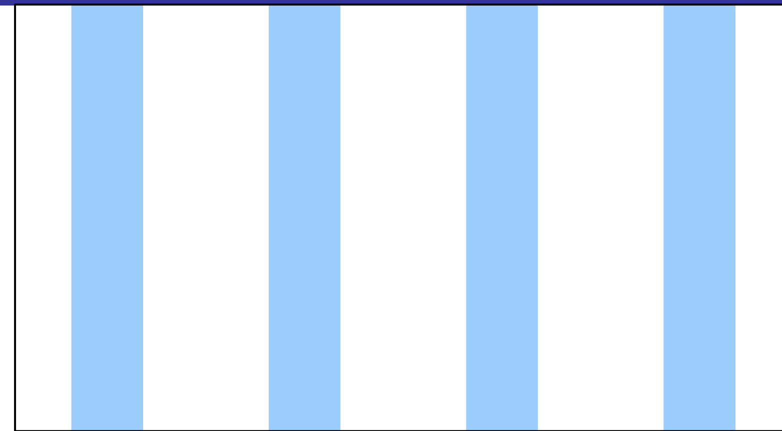
n&k Technology, Inc.

Template and Corresponding Imprint Measurement

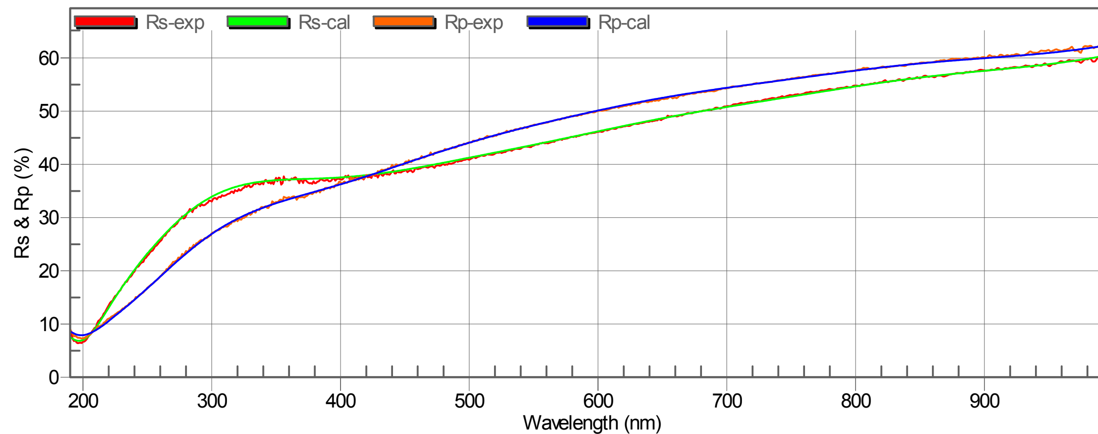
DTR Imprint Sample Model and Data Fit



Cross Section



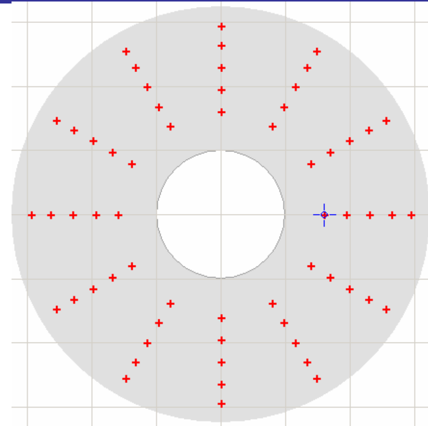
Top-Down, Pitch=120nm



Typical Analysis Fit

n&k Technology, Inc.

Template & Corresponding DTR Disk Parameters Simultaneously Measured and Mapped



Results for a 60 Point Radial Map

<u>Template</u>

- Quartz Etch Depth
  - Mean = 85.2nm, STD = 1.1nm
- Top CD
  - Mean = 51.9nm, STD = 6.0nm
- Bottom CD
  - Mean = 38.4nm, STD = 5.0nm
- Sidewall Angle
  - Mean = 82.8°, STD = 0.2°

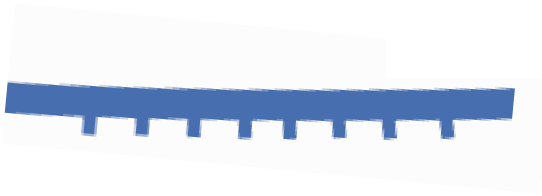
<u>Corresponding DTR Imprint Disk</u>

- Polymer Height
  - Mean = 84.1nm, STD = 2.3nm
- Residual Layer Thickness
  - Mean = 27.8nm, STD = 6.9nm
- Top CD
  - Mean = 83.3nm, STD = 5.2nm
- Bottom CD
  - Mean = 74.7nm, STD = 6.3nm
- Sidewall Angle
  - Mean = 85.5°, STD = 0.7°

n&k Technology, Inc.

CD Correspondence Between Template and DTR Imprint Disk

Good Correlation between the Template and Imprint Sample – Same Uniformity Pattern



Template Pitch — Bottom CD
Mean = 120nm — 38.4nm = 81.6nm
Std Dev. = 5.0nm

Imprint Disk Top CD
Mean = 83.3nm
Std Dev. = 5.2nm

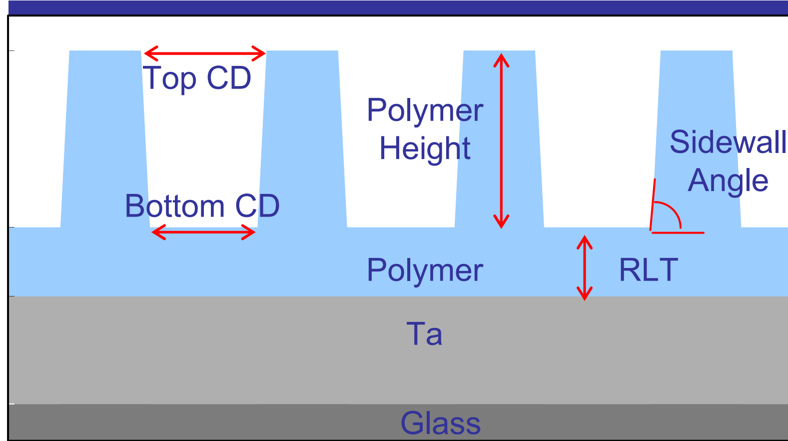
Template Pitch — Top CD
Mean = 120nm — 51.9nm = 68.1nm
Std Dev. = 6.0nm

Imprint Disk Bottom CD
Mean = 74.7nm
Std Dev. = 6.3nm

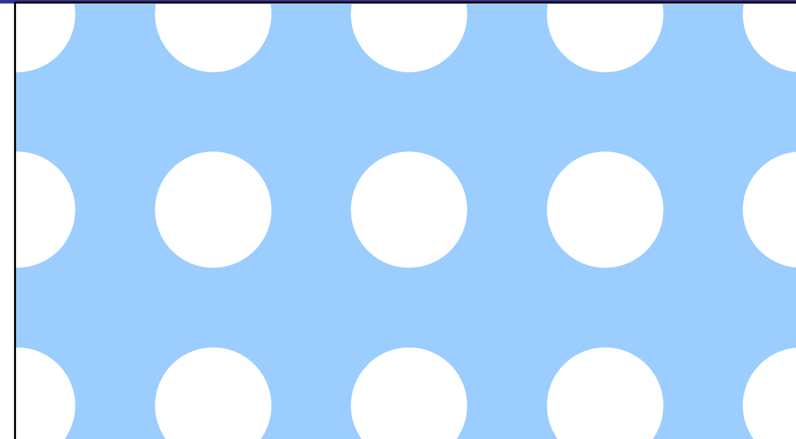
Uniformity pattern between Template and DTR Disk were similar in both cases

n&k Technology, Inc.

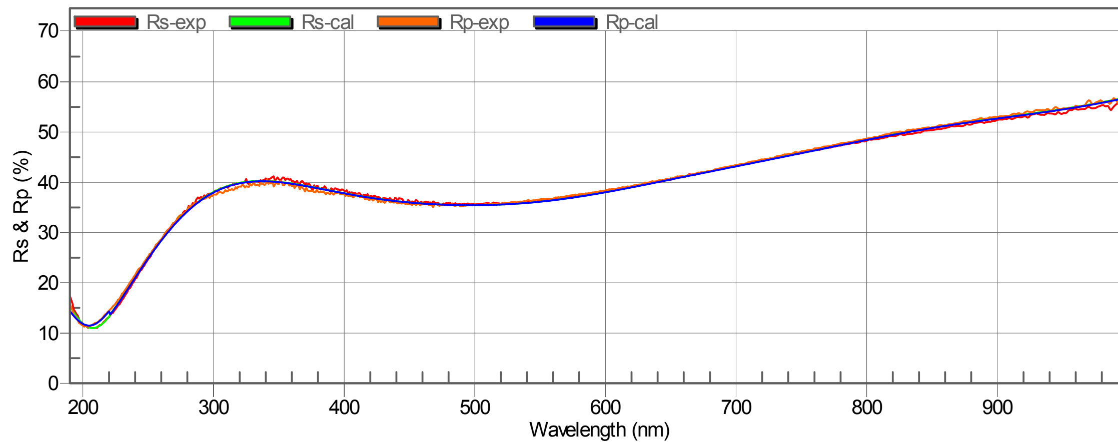
BPM Measurements



Cross Section



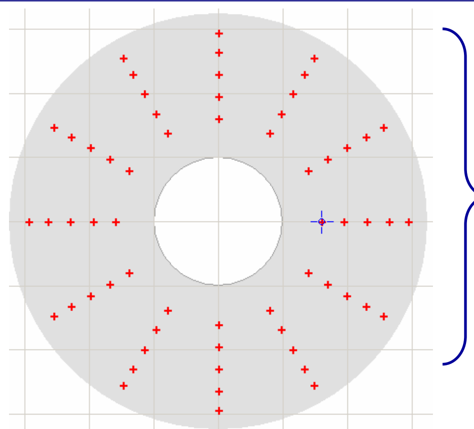
Top-Down, Pitch=36nm



Typical Analysis Fit

n&k Technology, Inc.

BPM Disk
Parameters Simultaneously Measured and Mapped

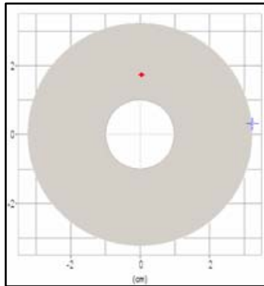


Results for a 60 Point Radial Map

- Polymer Height
  - Mean = 74.1nm, STD = 1.9nm
- Residual Layer Thickness
  - Mean = 29.8nm, STD = 2.5nm
- Top CD
  - Mean = 26.8nm, STD = 0.6nm
- Bottom CD
  - Mean = 17.2nm, STD = 0.9nm
- Sidewall Angle
  - Mean = 85.6°, STD = 0.5°

n&k Technology, Inc.

BPM Results
Static & Dynamic Repeatability



- Repeatability Measurements performed at 1 location
- For Static Repeatability, the location is measured 10 times without stage movement
- For Dynamic Repeatability, the location is measured 10 times with sample load/unload between measurements

Parameter	Static Repeatability		Dynamic Repeatability	
	Mean	Std Dev (1σ)	Mean	Std Dev (1σ)
Polymer Height (nm)	74.2	0.33	72.4	2.24
Residual Layer Thickness (nm)	29.3	0.15	33.2	1.16
Top CD (nm)	26.5	0.09	26.7	0.69
Bottom CD (nm)	16.8	0.10	17.7	0.82
Sidewall Angle (°)	85.7	0.06	86.0	0.53

Summary

- Sensitivity of optical metrology is the key challenge in measuring Imprint Templates, DTR and BPM Disks
- To surmount this challenge, an optical metrology system must include the following features:
  - A high signal to noise ratio over the entire measured WL range,
  - Cover a wide range of wavelengths,
    - Since changes in measured spectrum, caused by variations of parameters, can affect various regions of the spectrum
  - Include transmittance, not just reflectance, for measuring templates
  - A valid physical model for analysis
  - Include proper hardware for handling disks
- It is shown that the n&k Gemini includes the above mentioned features

Thank You

n&k
Technology, Inc.