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Large Spot Reflectometry for CVD Process Control

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Texas Instruments, Inc.

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Outline

- Project Goals
- Hardware
  - Verity SP2002 Reflectometer
  - Integration of Reflectometer on NVLS Concept Two Speed Tool
- Data and Analysis
- Summary

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Ultimate Goals

- Integrate low-cost film thickness measurement on CVD tool to provide film measurement on every wafer with short lag-time for
  - run-to-run feedback process control
  - excursion detection

    (1st part of Fault Detection and Classification (FDC))

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Goals of this Project

- Integrate large-spot spectral reflectometer on Novellus Concept Two Speed CVD Tool in TI Kilby Wafer Fab
- Semi-automate data collection with no through-put hit
- Start to evaluate integrated measurement capability
  - Compare to stand-alone measurements
  - Show film thickness variance:

    --across-wafer --wafer-to-wafer,

    --lot-to-lot --chamber-to-chamber
- Minimal resource requirements from Texas Instruments and Novellus

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SP2002 Reflectometer

Xenon flash lamp

- –broad-band light source
- –short flash stops wafer motion
- –synchronized with spectral data acquisition

Multichannel spectrograph

– UV- NIR (200-800nm)

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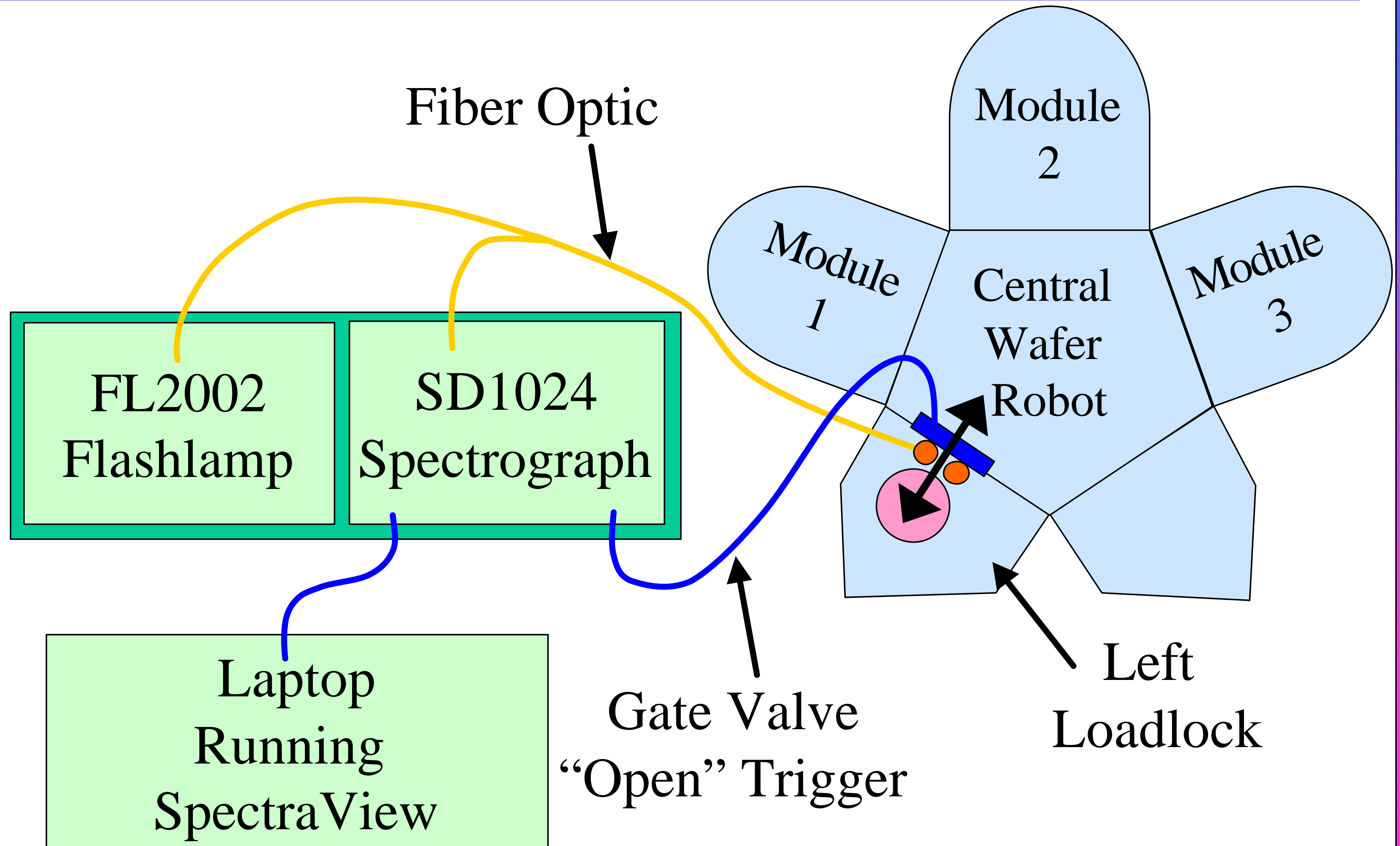
System Diagram



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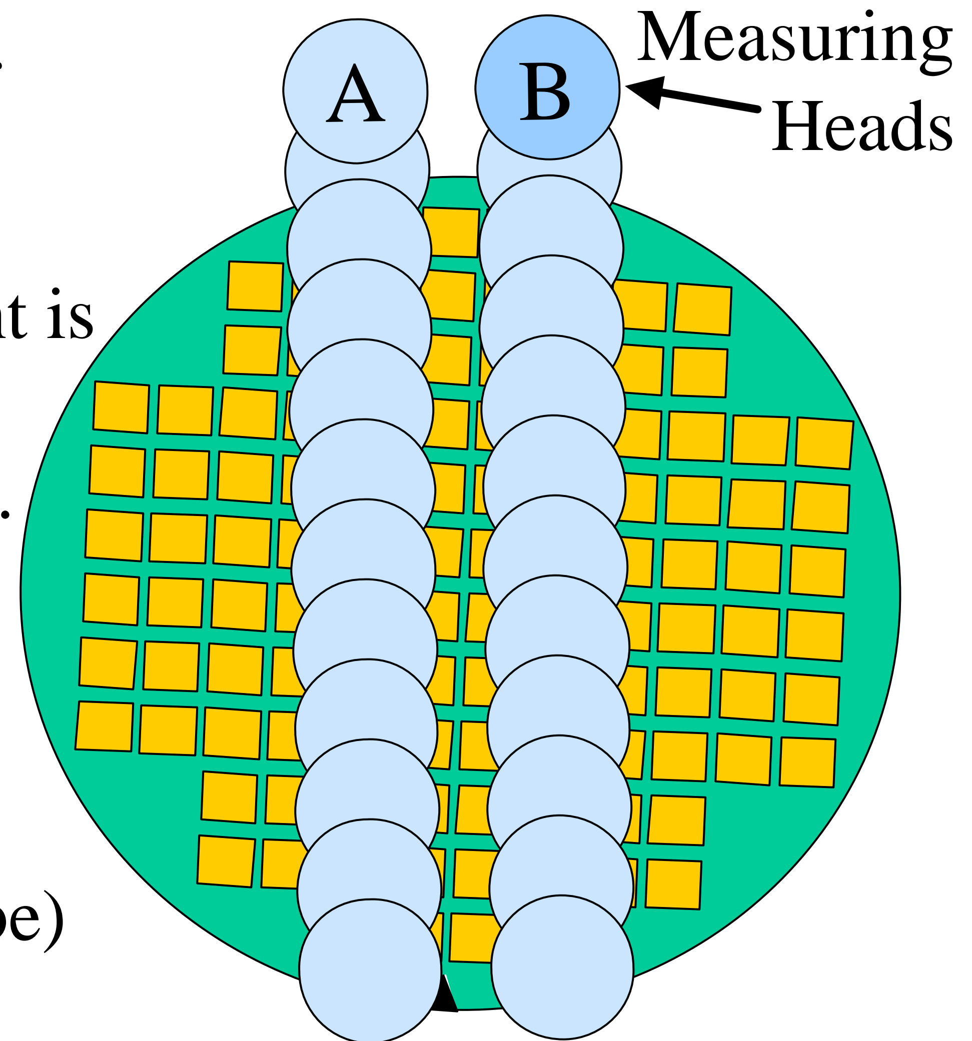
Wafer Measurements

Robot moves the wafer under the measurement heads.

Probe spot-to-wafer alignment is dependant on prior wafer alignment and robot handling.

Flashlamp sampling
-- stops wafer motion
-- flashing every 30 msec.
(12 measurements/wafer/probe)

Large spot (1 in. dia.) for die-scale averaging



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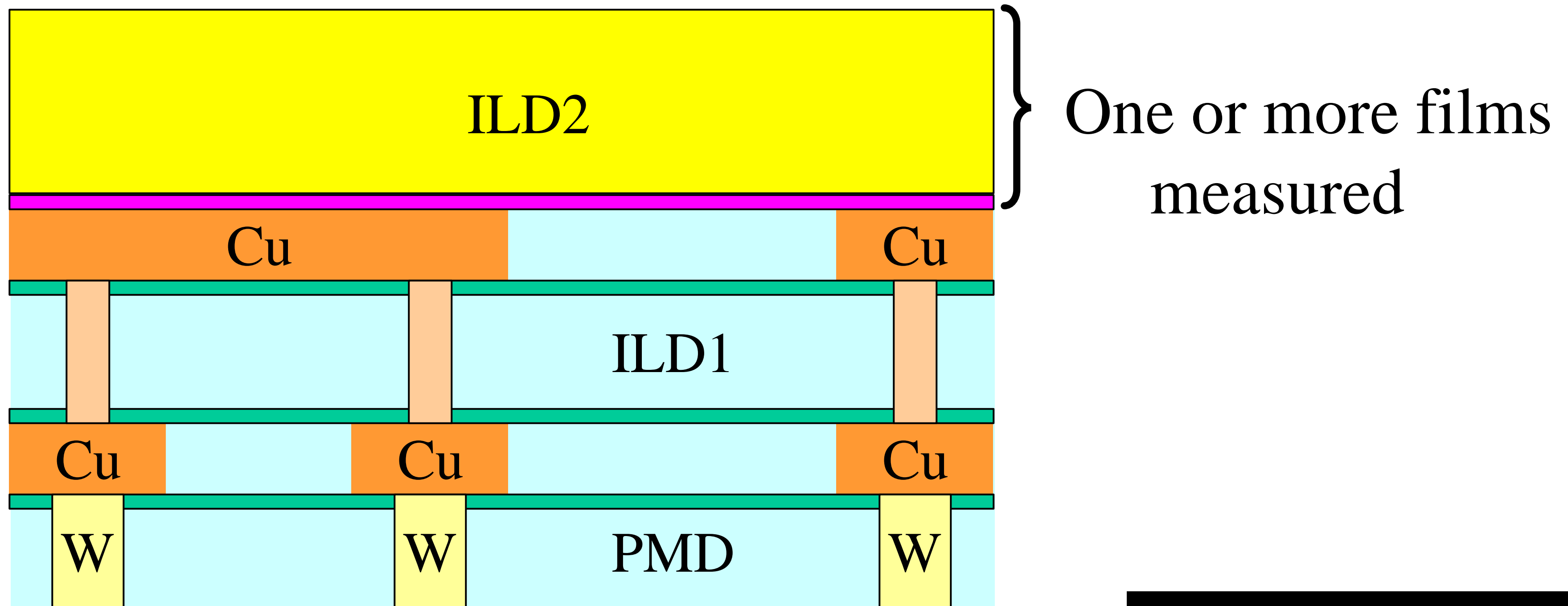
Wafer Structure

Minimum information required
- Uppermost ILD stack structure
- Nominal thickness
- Film optical indices



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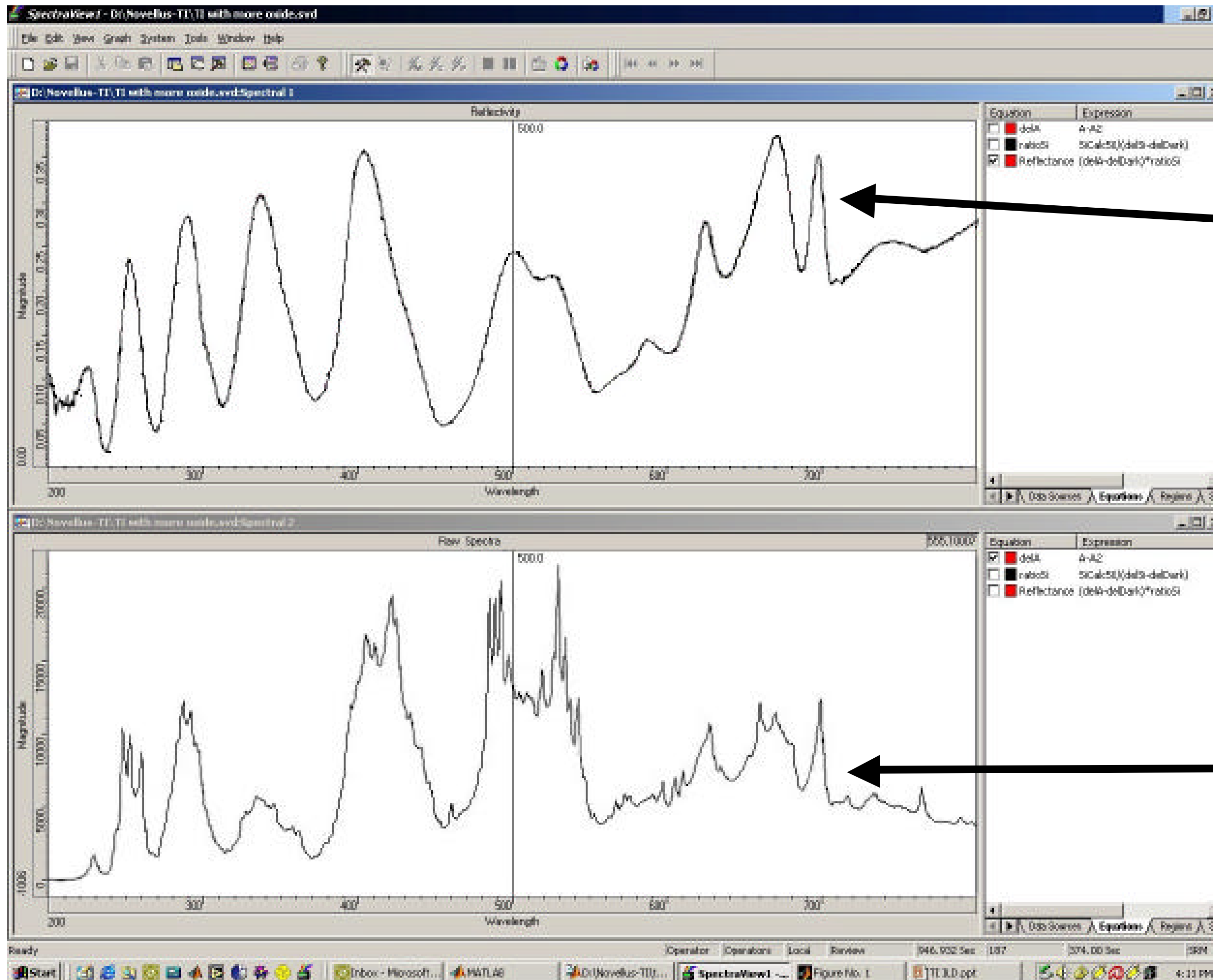
SpectraView Data



Normalized Reflectivity Data

Raw Data

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Analysis

- Algorithm applied to
  - **Inputs :**
    - Normalized reflectometry data
    - Film stack description
    - Film material optical indices
    - Nominal thicknesses
  - **Outputs:**
    - Measured thicknesses

Some algorithm optimization is required for different ILD layers

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Analysis

- Correlating the thickness measurements with wafer and chamber processing information yields film thickness average and variance
  - Across the wafer
  - Wafer-to-wafer
  - Lot-to-lot
  - Chamber-to-chamber

- Study variables
  - Die size
  - Film thicknesses
  - ILD levels
  - ILD materials

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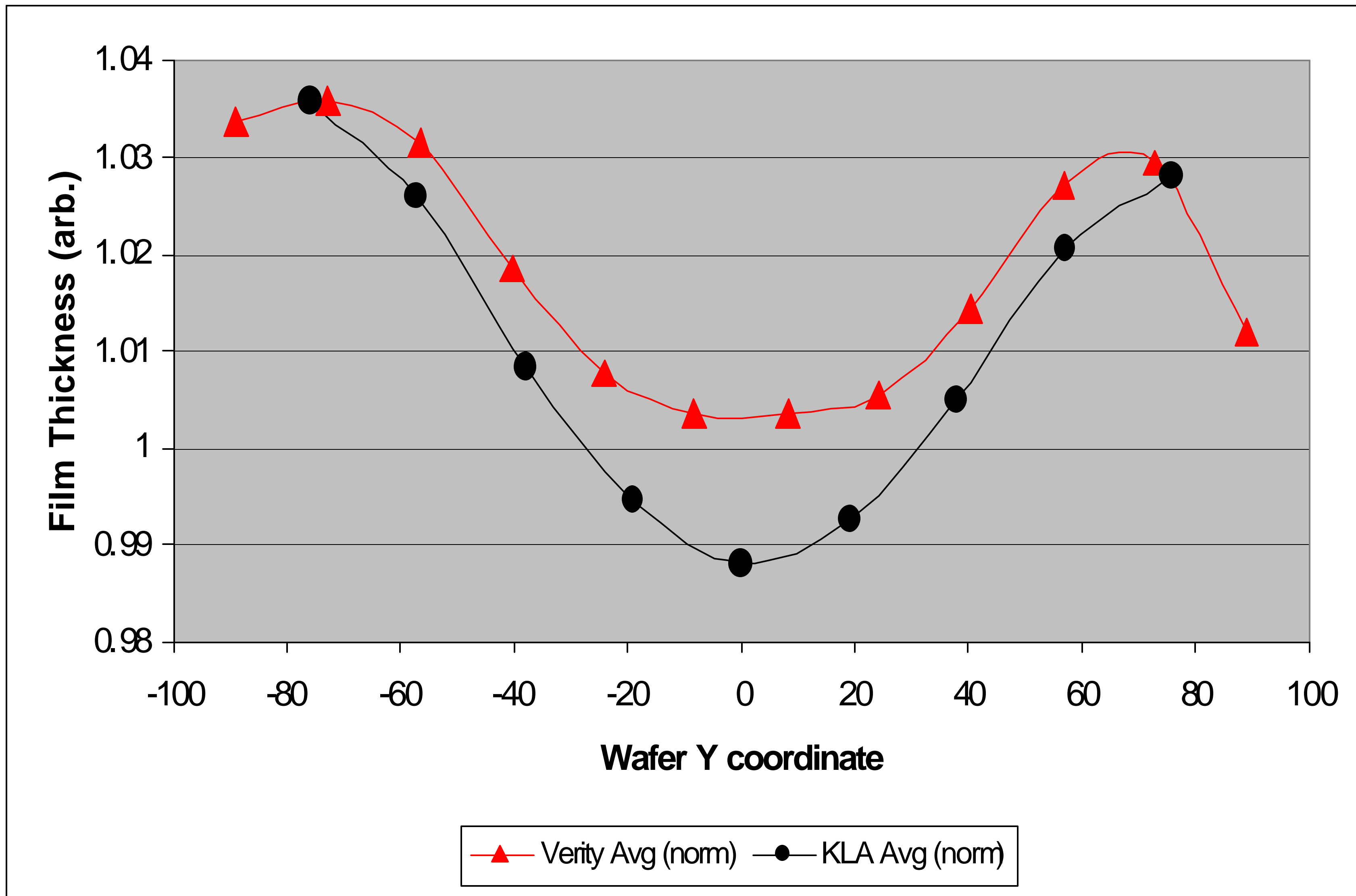
Pilot Wafer (ILD Film on Si)



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ILD over Tungsten Plug

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Contact Level

- Study variables
  - Die size < 5 x 5 mm
  - ILD level = Contact
    - Dielectric deposition on nitride over patterned tungsten plugs
  - ILD material = FSG

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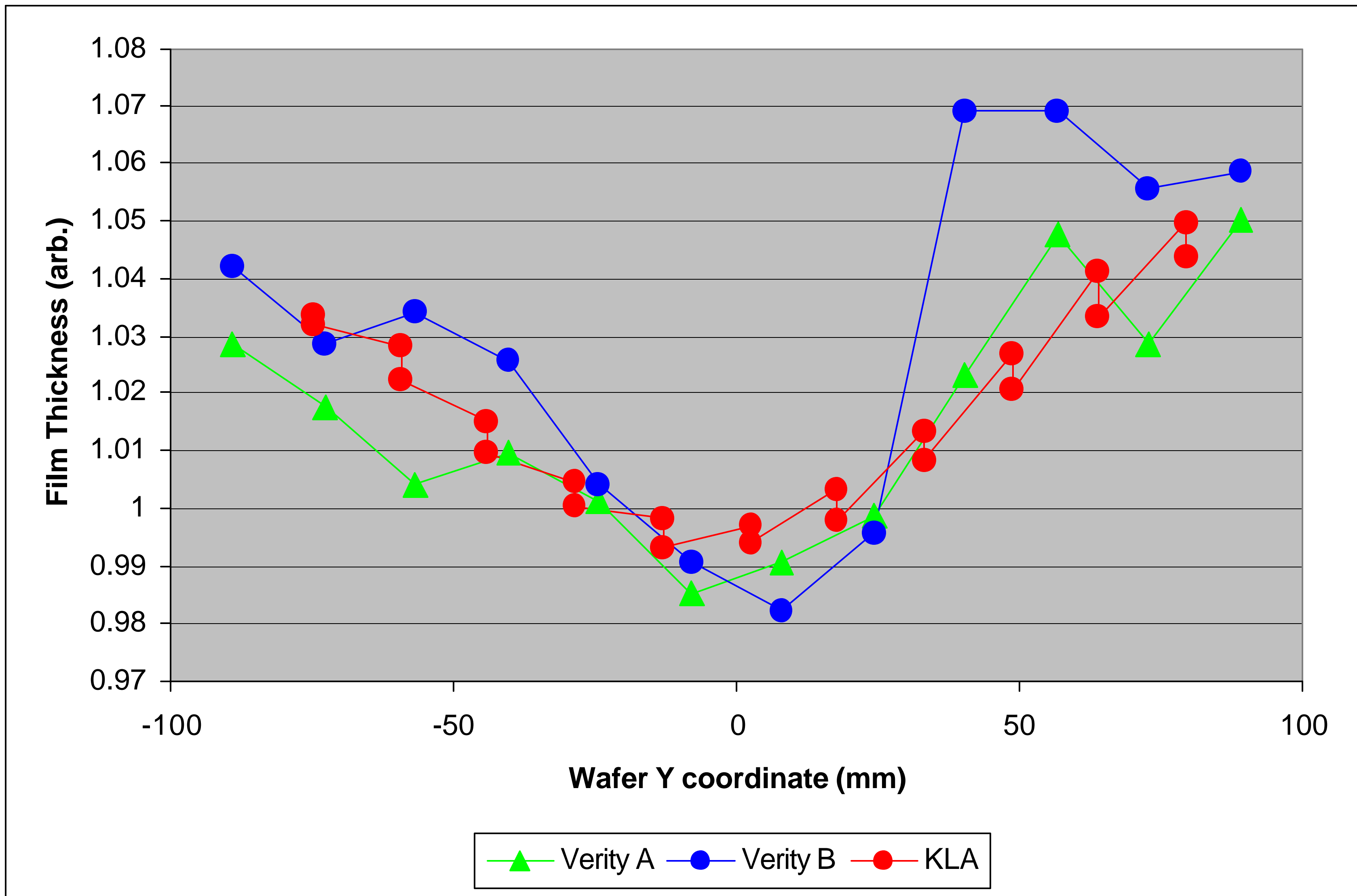
WIW Variation



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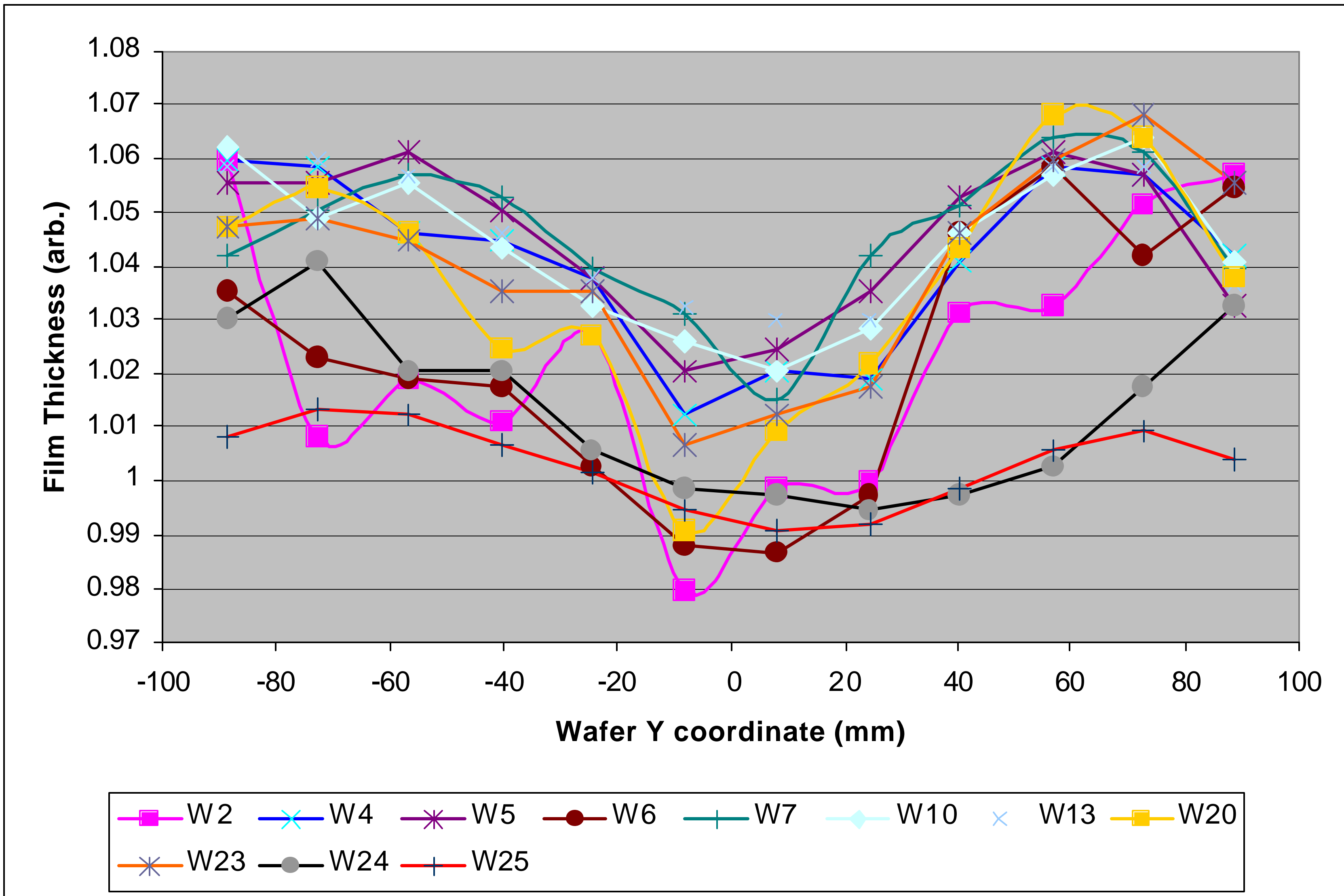
W2W Variation of Module #3



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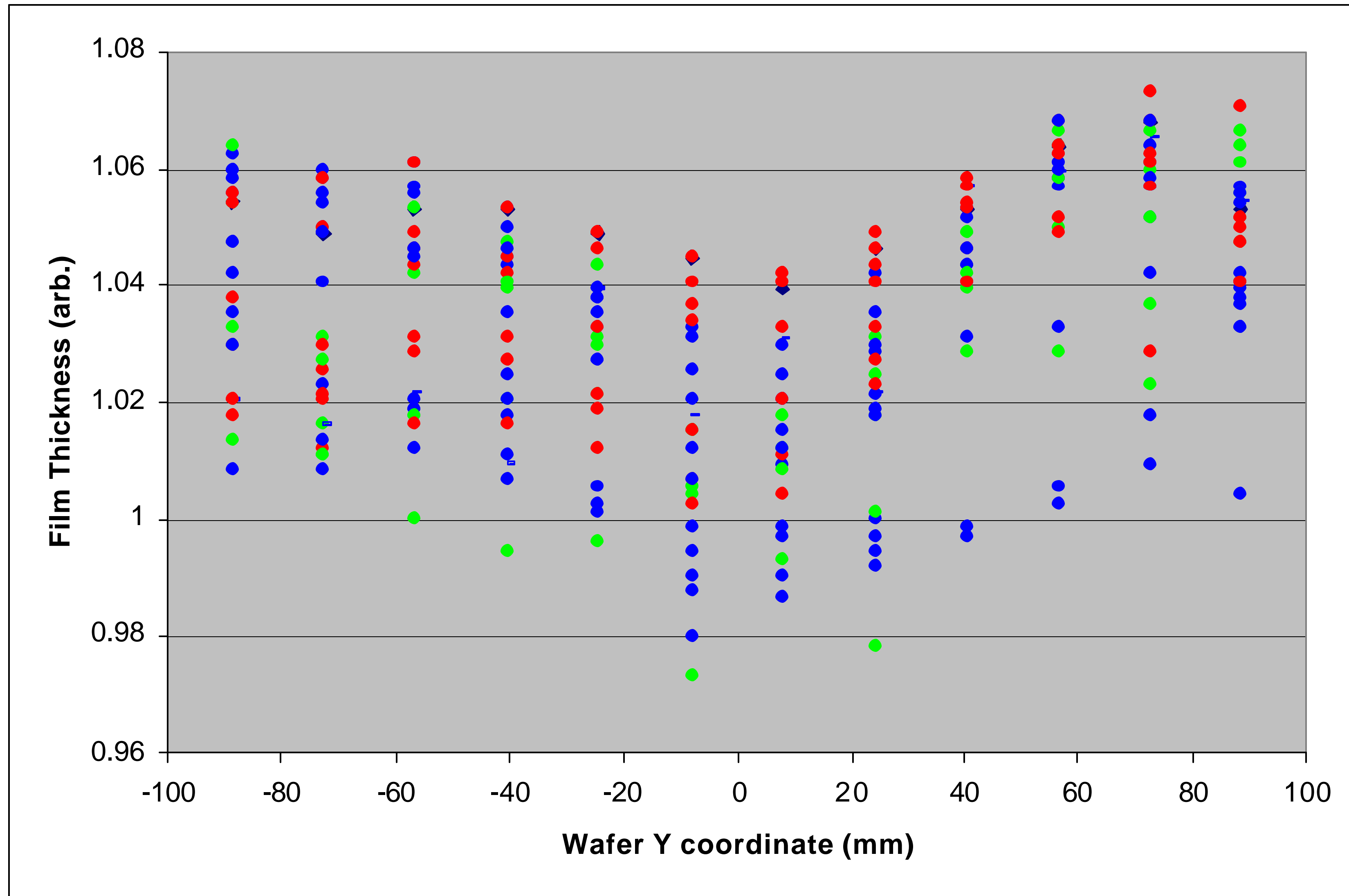
Within Lot Variation



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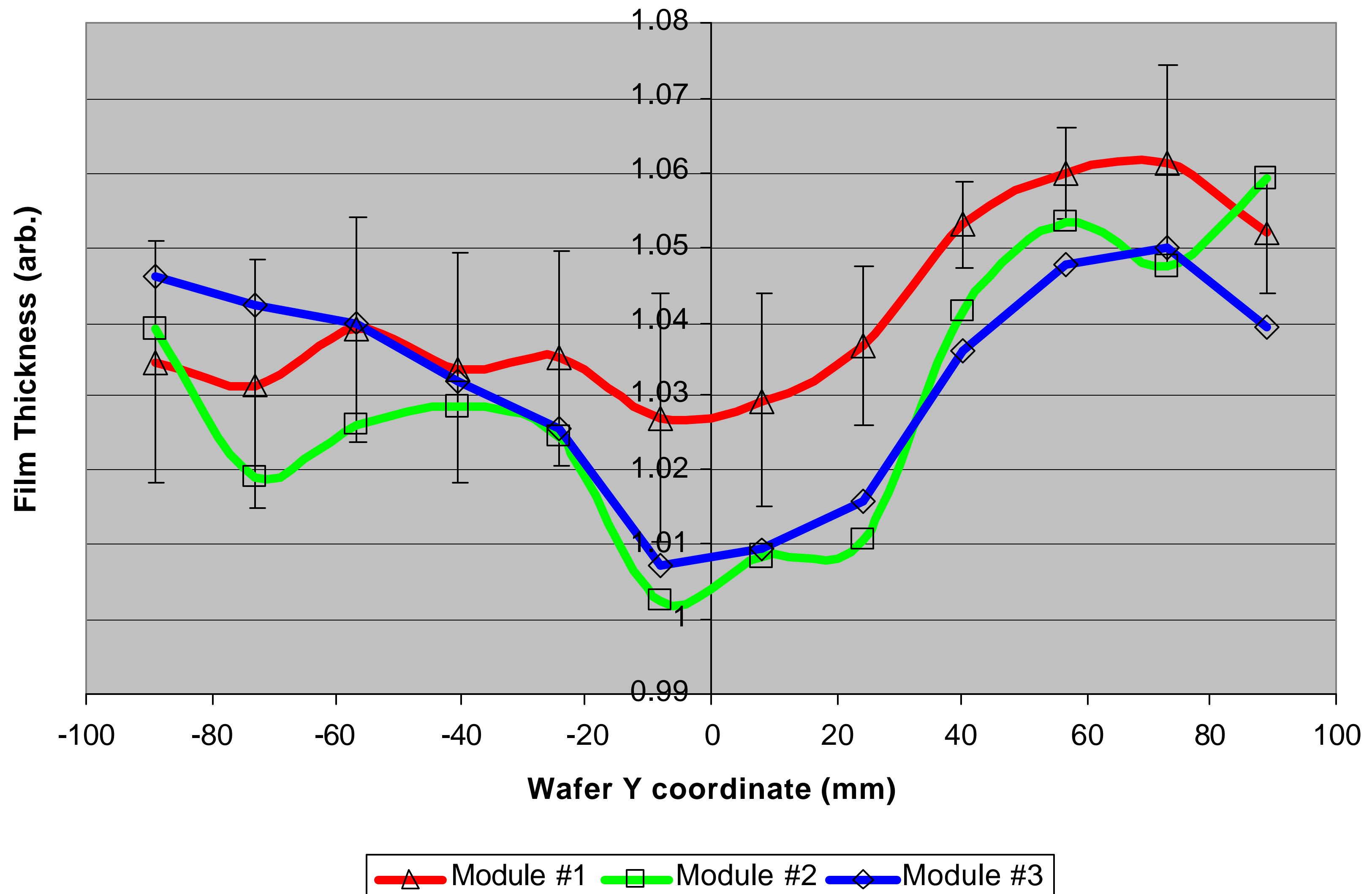
Variation of 3 Modules



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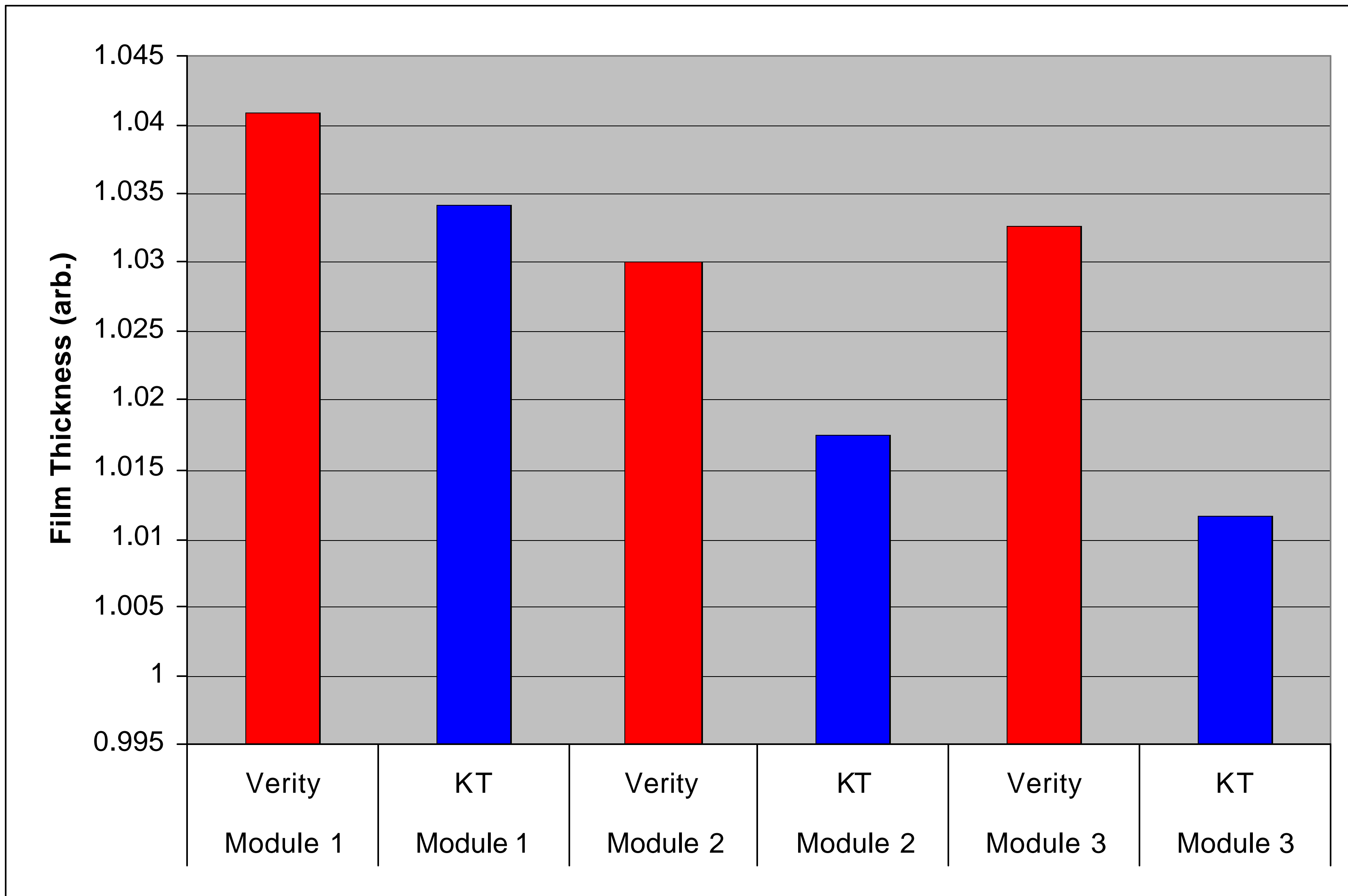
Average Wafer Variation



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ILD over Copper Damascene

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Damascene Level

- Study variables
  - Die size < 10 x 10 mm
  - ILD level = ILD-5
    - Dielectric deposition on nitride over planarized copper Damascene
  - ILD material = FSG

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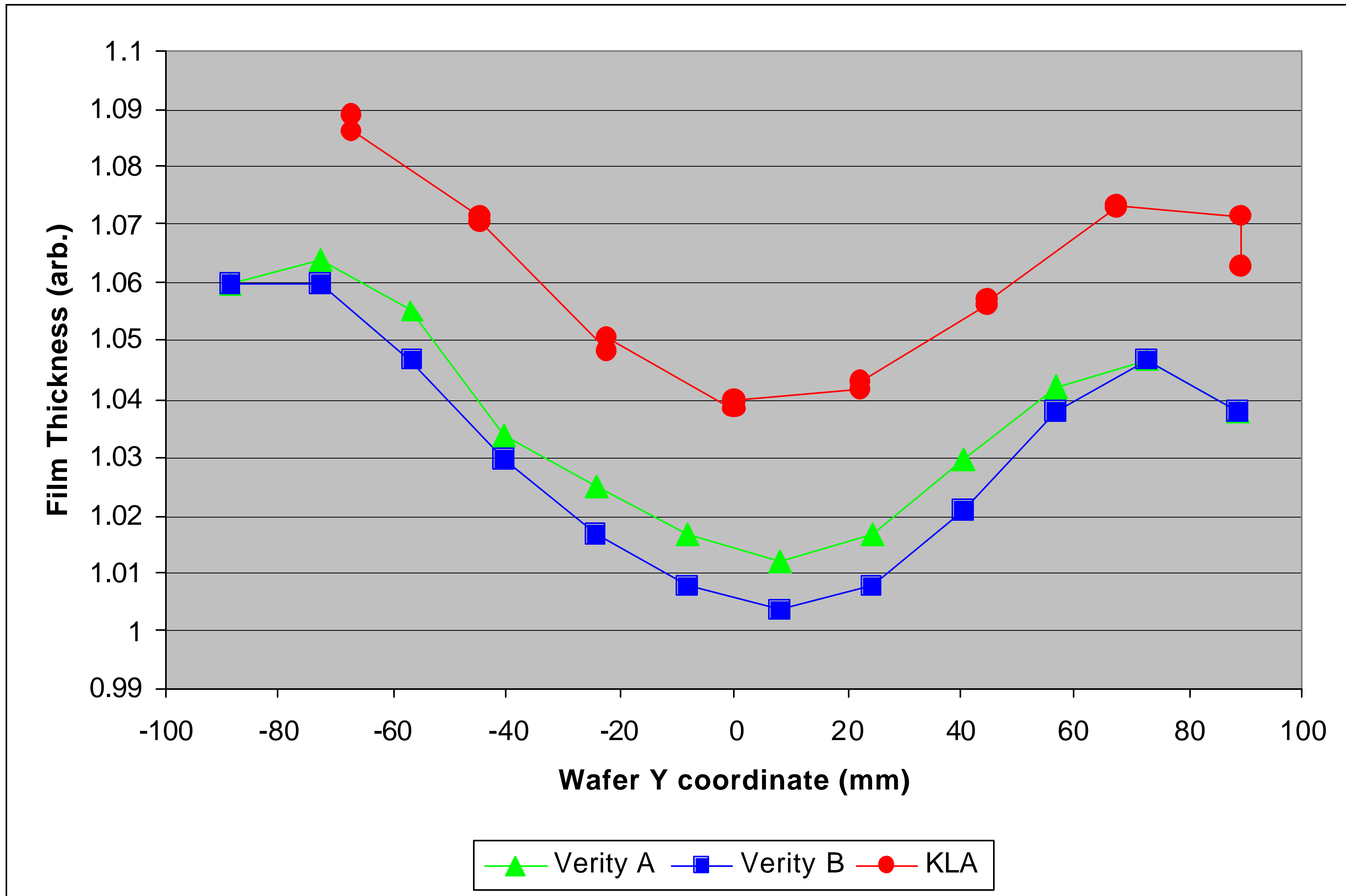
WIW Variation



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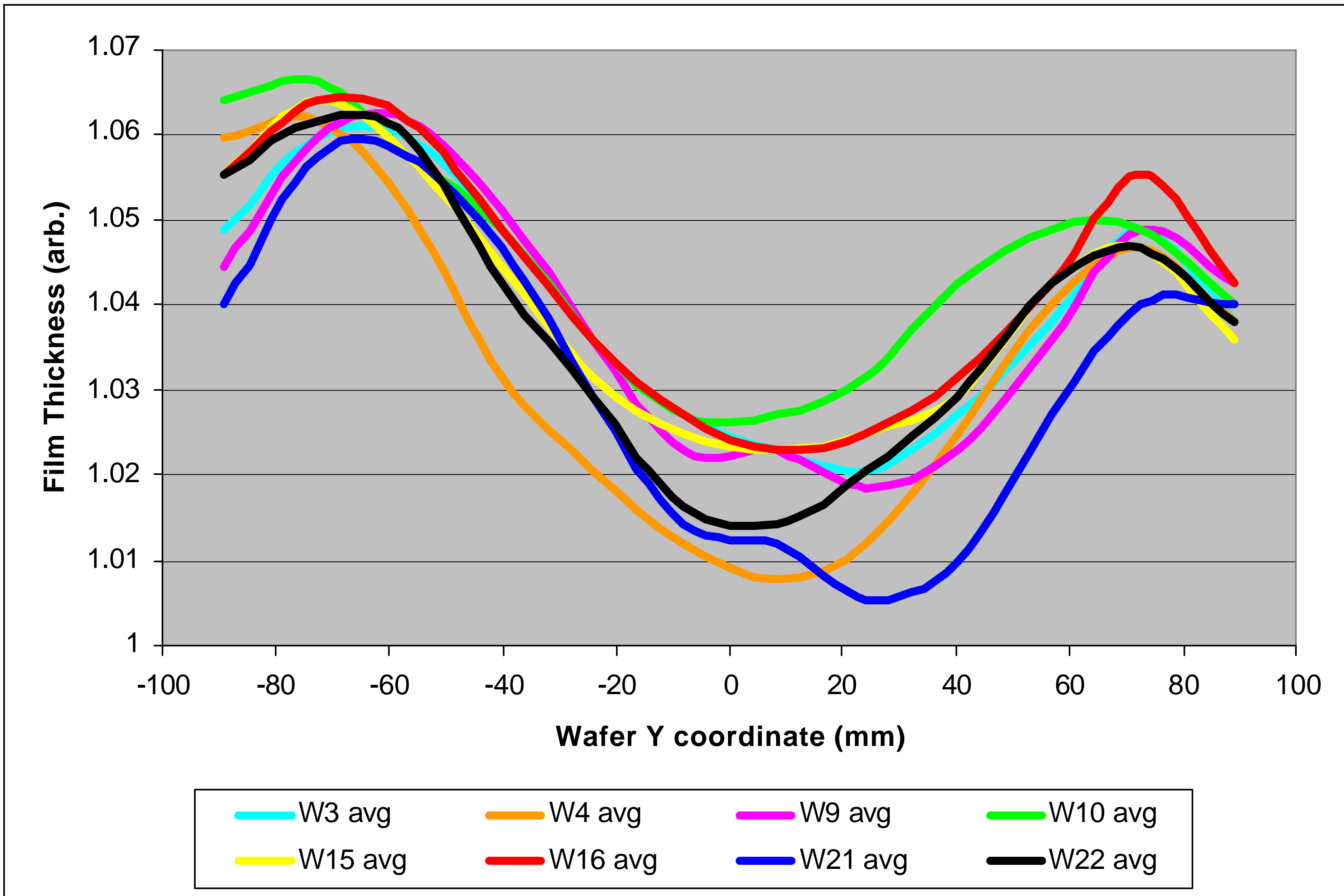
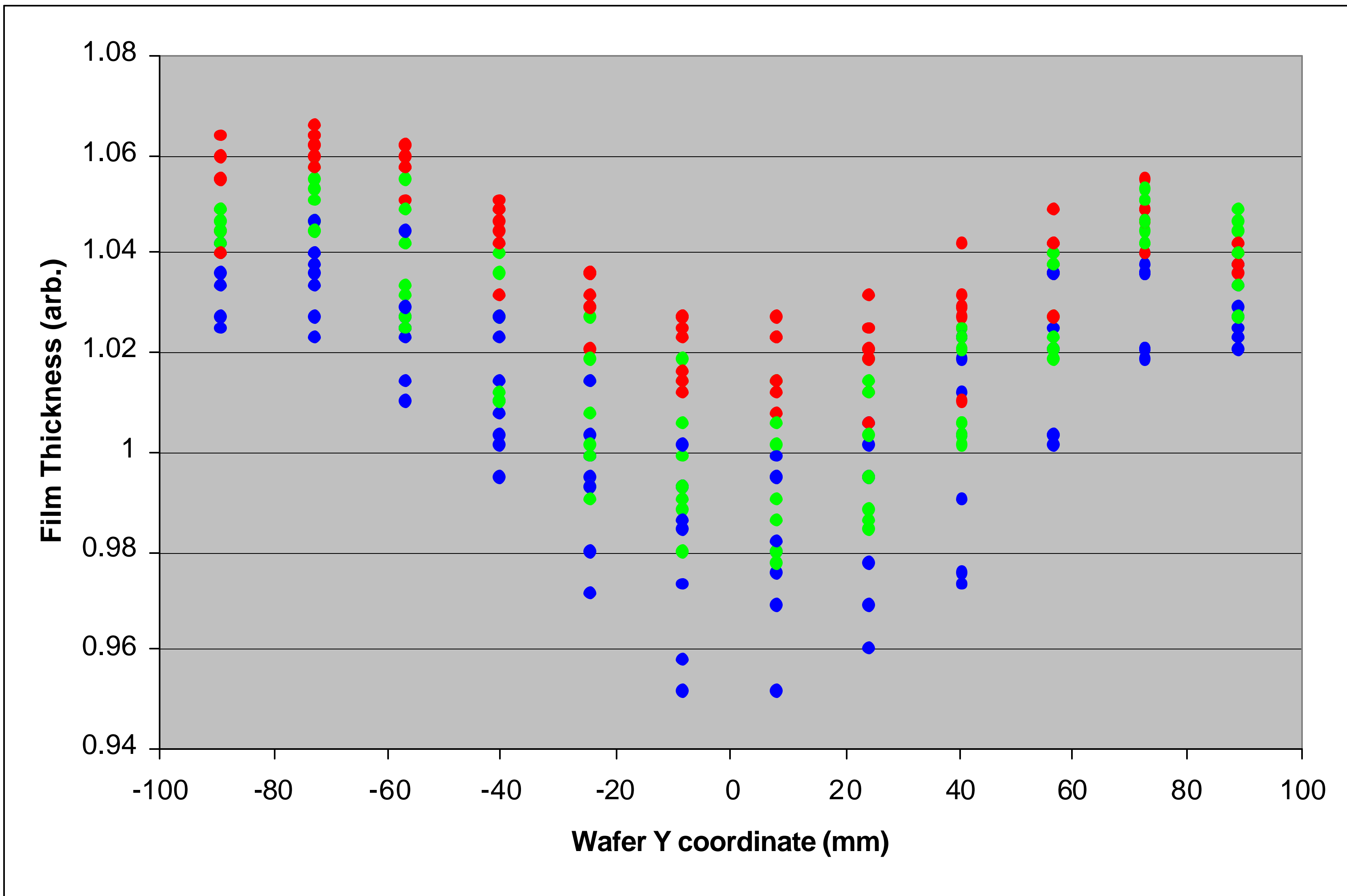
W2W Variation of Module #1



Within Lot Variation



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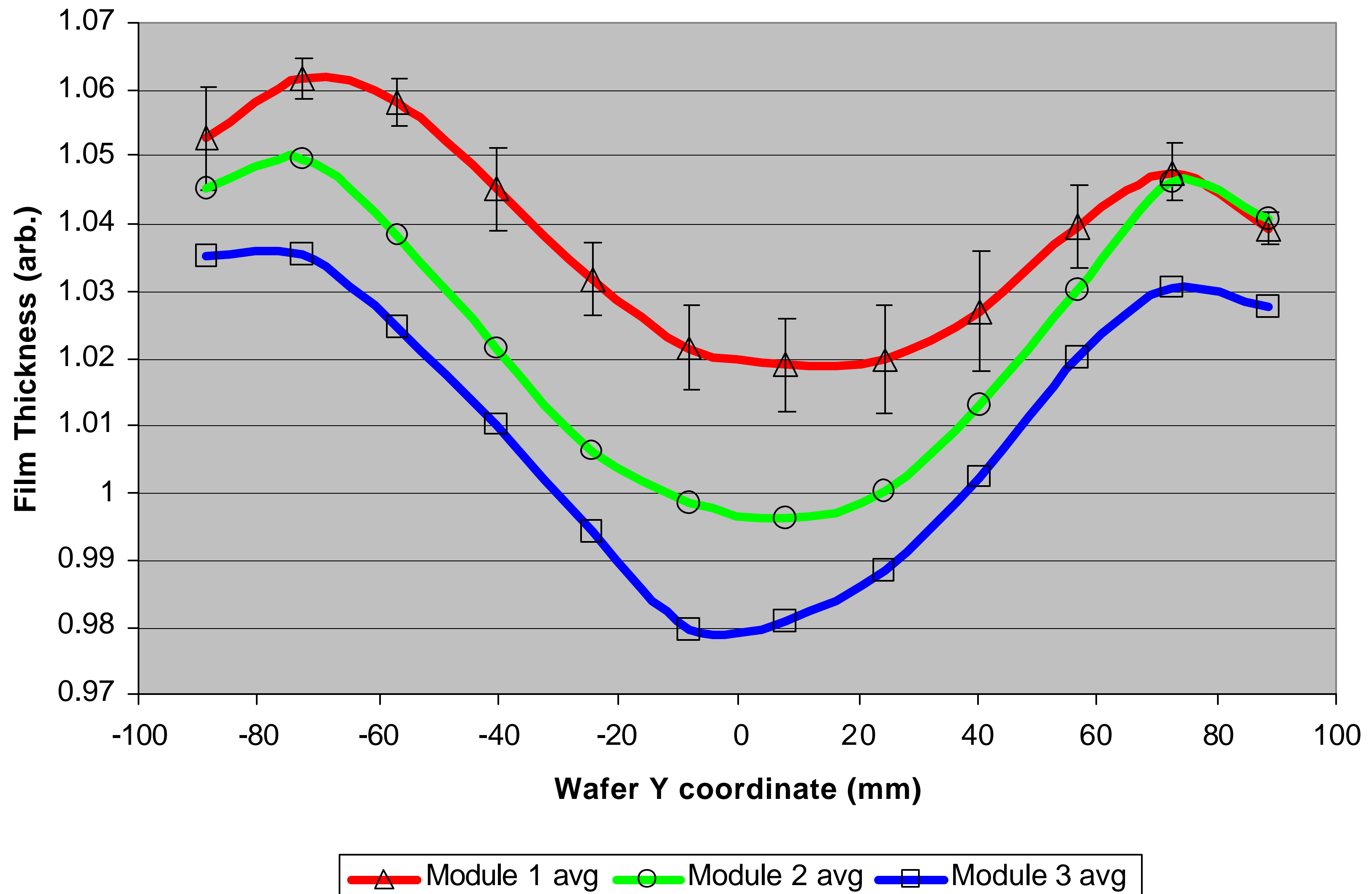
Variation of 3 Modules



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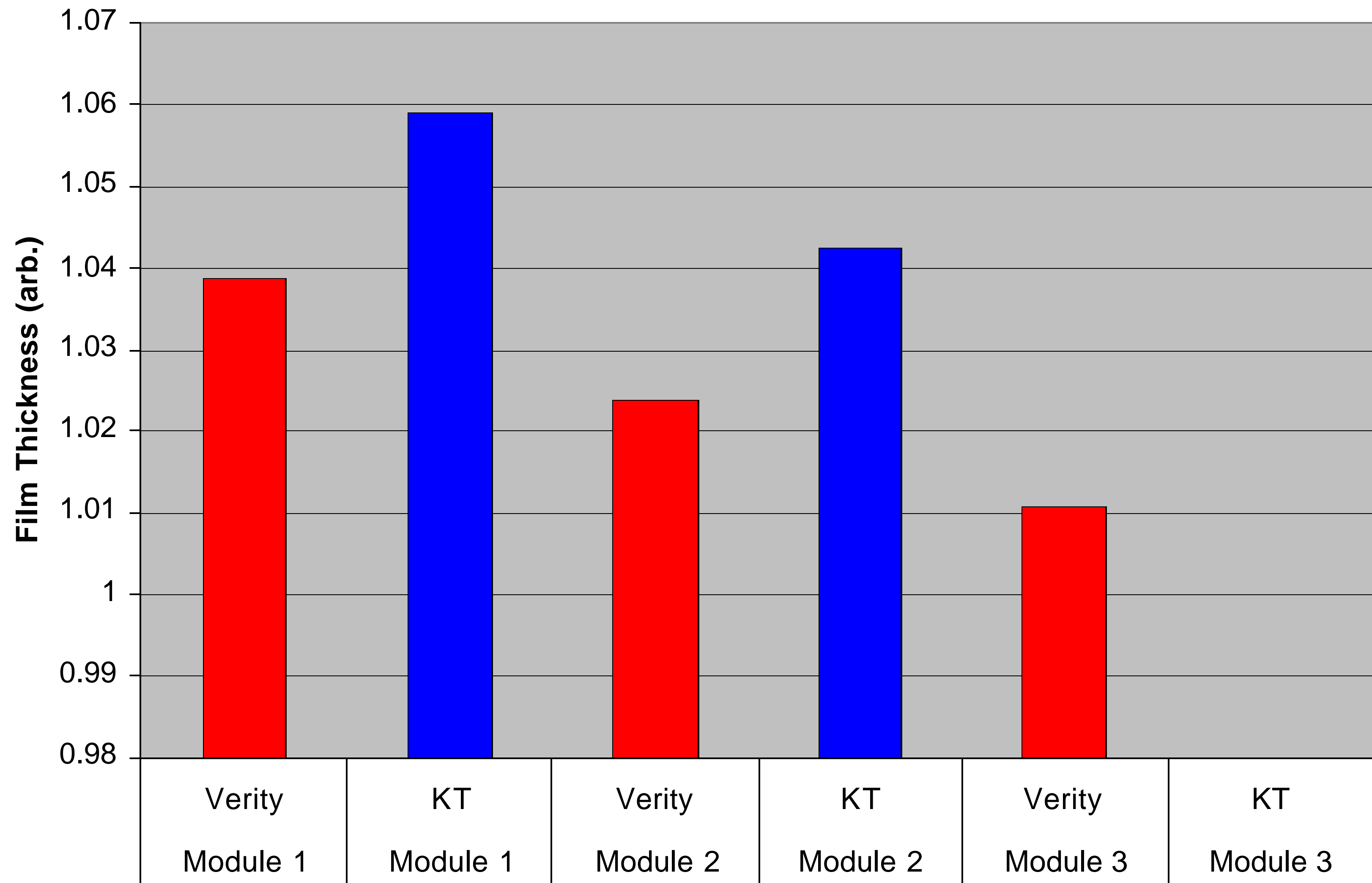
Average Wafer Variation



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Benefits of IM for CVD

- No impact on through-put
- Film thickness profile measurements ***on every wafer*** increases visibility on the process
  - Average thickness
  - Thickness profile map
  - Chamber matching
  - Basis for lot statistics
  - Measuring product wafers can reduce the number of test wafers
- Short lag-time enables new capabilities
  - Run-to-run feedback process control
  - Rapid excursion detection

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Potential ROI

- Eliminate or reduce monitor wafers
  - **Process more product wafers**
  - **Increase fab revenue**
- Monitor and track performance variance between specific process modules -- not just the average of a 3-module process tool
  - **Improves "tool" matching**
- Detect onset of tool and/or process excursion(s)
  - **Save several lots from being misprocessed**
  - **Improve yield**
  - **Reduce tool CoO**
- Facilitates quick insertion of process module into process line after maintenance work
  - **Reduce downtime**
  - **Reduce tool CoO**
- Replace some scheduled maintenance with "need-based" maintenance
  - **Reduce downtime**
  - **Process more product wafers**

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Summary

- Large-spot spectral reflectometry integrated on CVD tools provides useful film thickness measurement information
  - Faster test wafer measurement
  - Measurement of patterned wafers to reduce test wafers
  - Short measurement lag-time for feedback process control
  - Rapid excursion detection (1st half of FDC)
- Integrated on Novellus tool
  - Opto-mechanical interface is satisfactory for now
  - Sensor-Tool coordination needs improvement
- Rigorous gauge study is required next

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