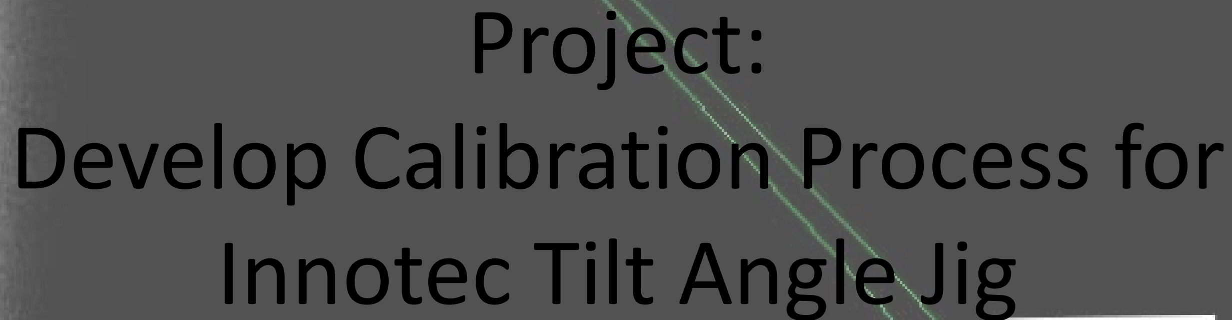
Project:
Develop Calibration Process for Innotec Tilt Angle Jig



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J Provine (mentor)

13 Dec 2011

Overview

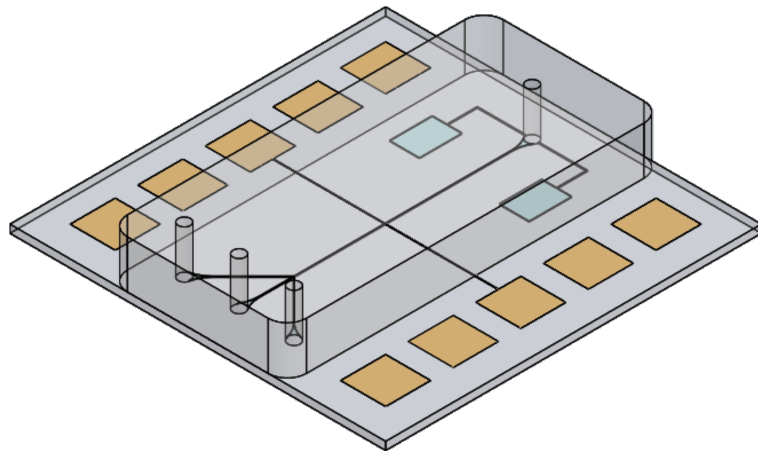
- Motivation
- Description of tool (innotec)
- Description of project
- Experimental procedure
- Data acquisition
- Data analysis
- Recommended process
- Results of test run

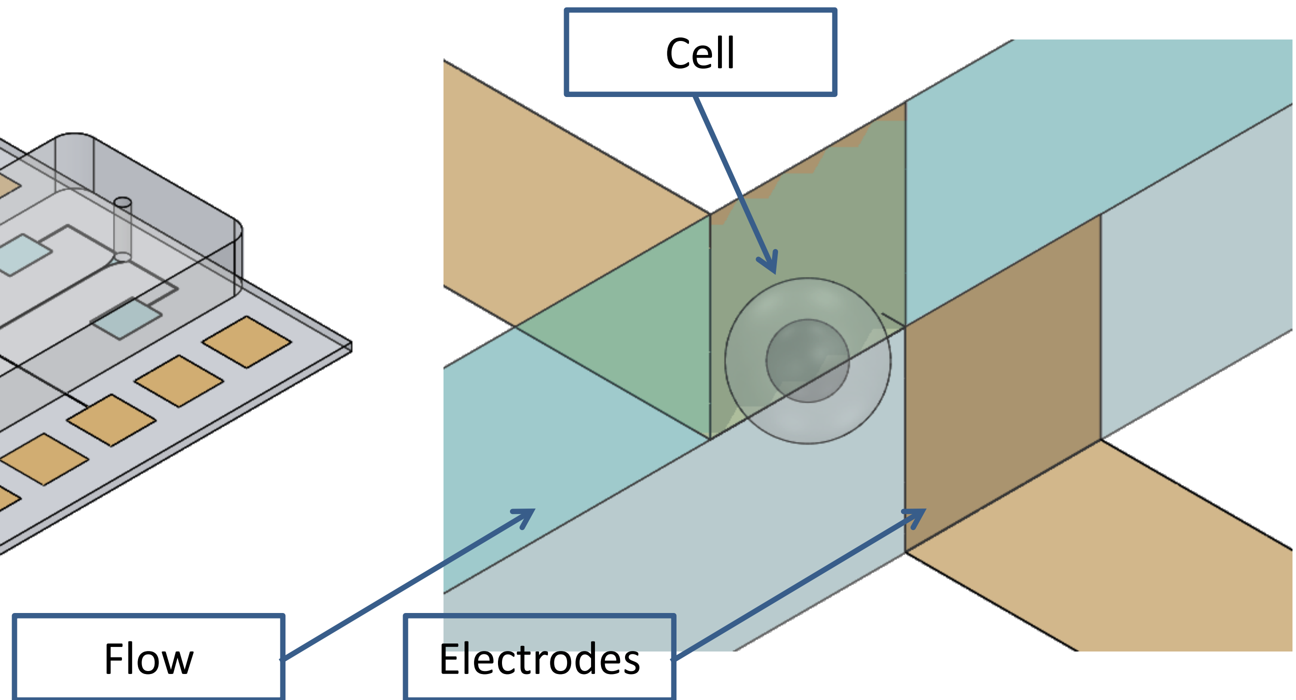
innotec at the SNF

Motivation

General layout microfluidic chip with electrodes

Close up patterned, sidewall electrodes





Description of tool (innotec)

An e-beam metal evaporation system capable of holding 22, 4” wafers.
A directional process allowing precisely controlled film thickness up to 1 μm.

Jig in planetary

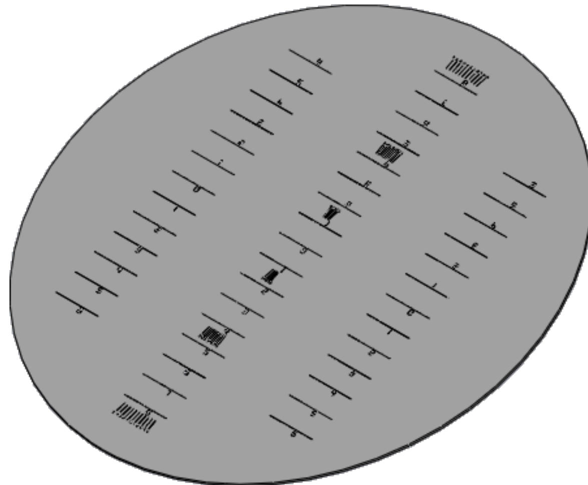
Tilt angle “gauge”

Planetary retrofitted with a tilt angle jig allowing wafer alignment at different angles.

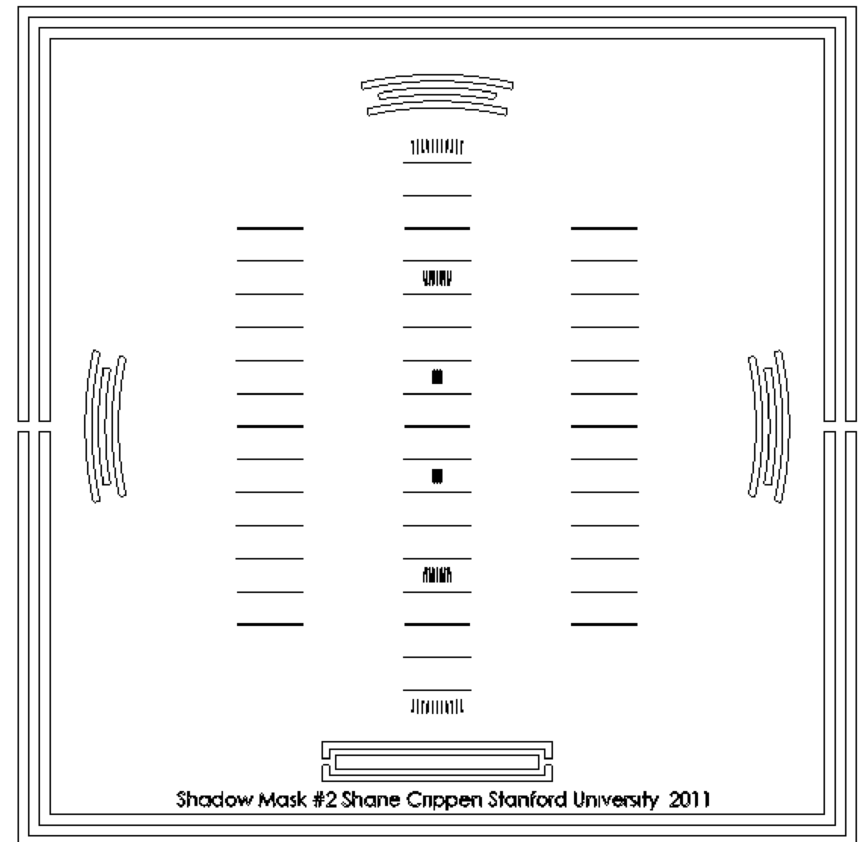
Description of project

Develop calibration process for tilt angle jig to determine angle of evaporation

- Standard lithography using transparency mask (karlsuss)
  - Horizontal slits to measure tilt
  - Angle slits to measure rotation
- STS DRIE (stsetch, DEEP)
  - Channels all 50 µm, 1:1 aspect ratio
- Metallization (innotec) 2000 Å Al



Trenches in silicon

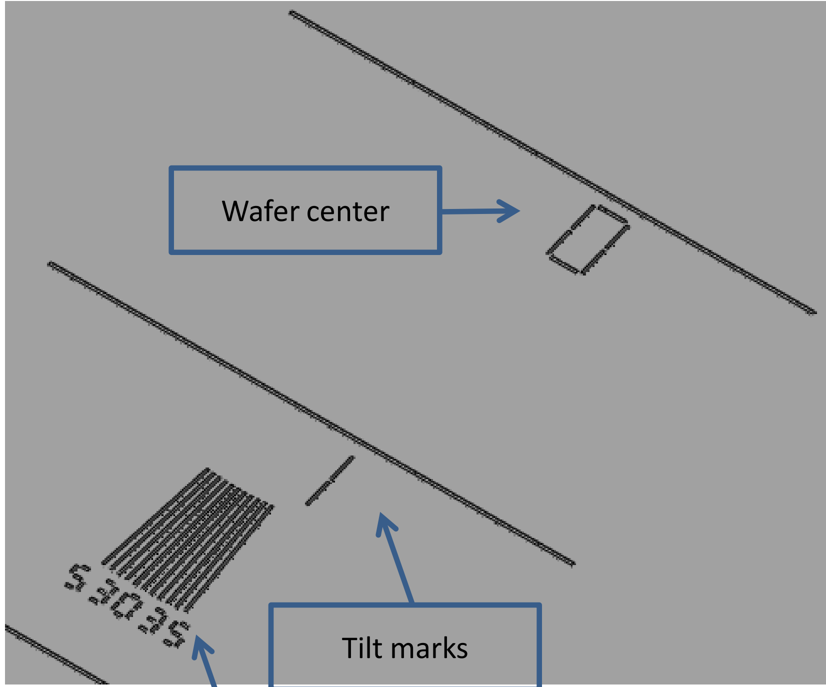


Transparency mask

Description of project

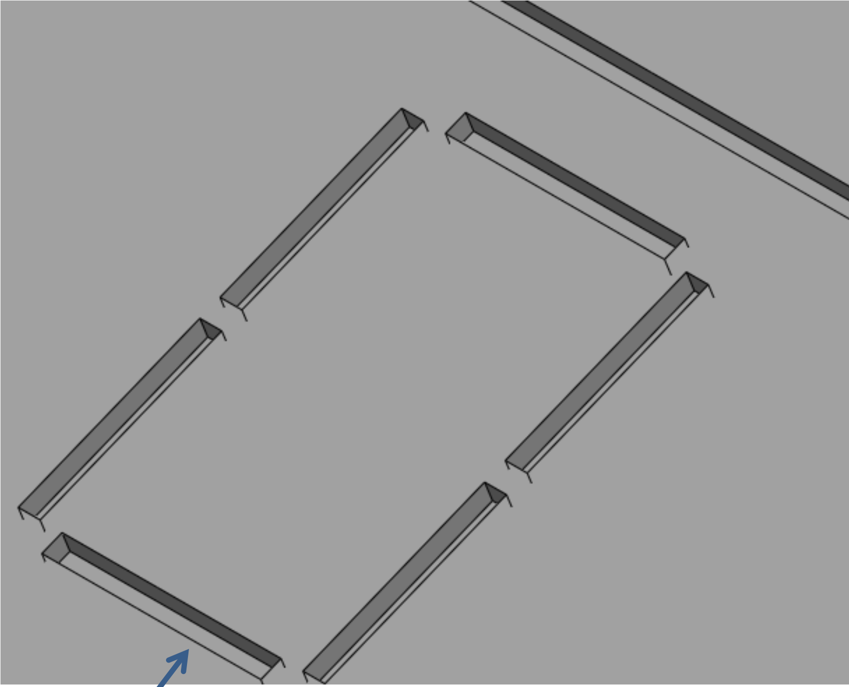
Near wafer center

(slits & scale)



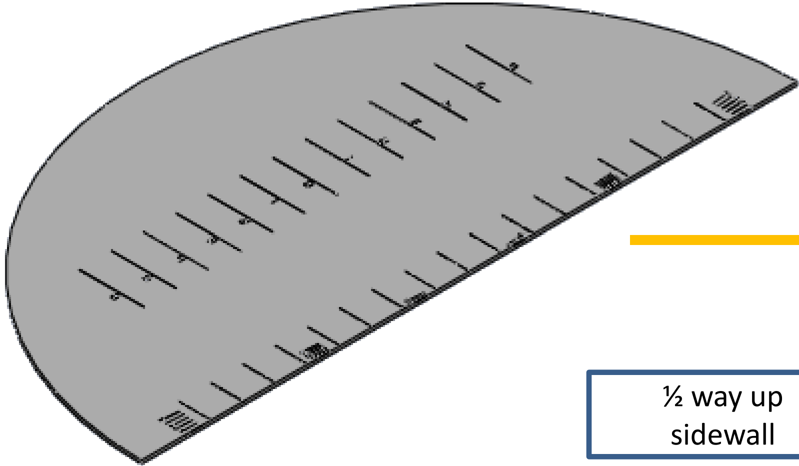
Closeup near wafer center

(slits & scale)



Description of project

Cut away



$$\text{jig tilt} = \operatorname{atan}\left(\frac{\text{trench width} - x}{\text{trench depth}}\right)$$

Single trench up close

Jig tilt angle

Incident source

27°

45°

63°

Thin film

½ way up sidewall

1:1 aspect ratio channels (50 μm)

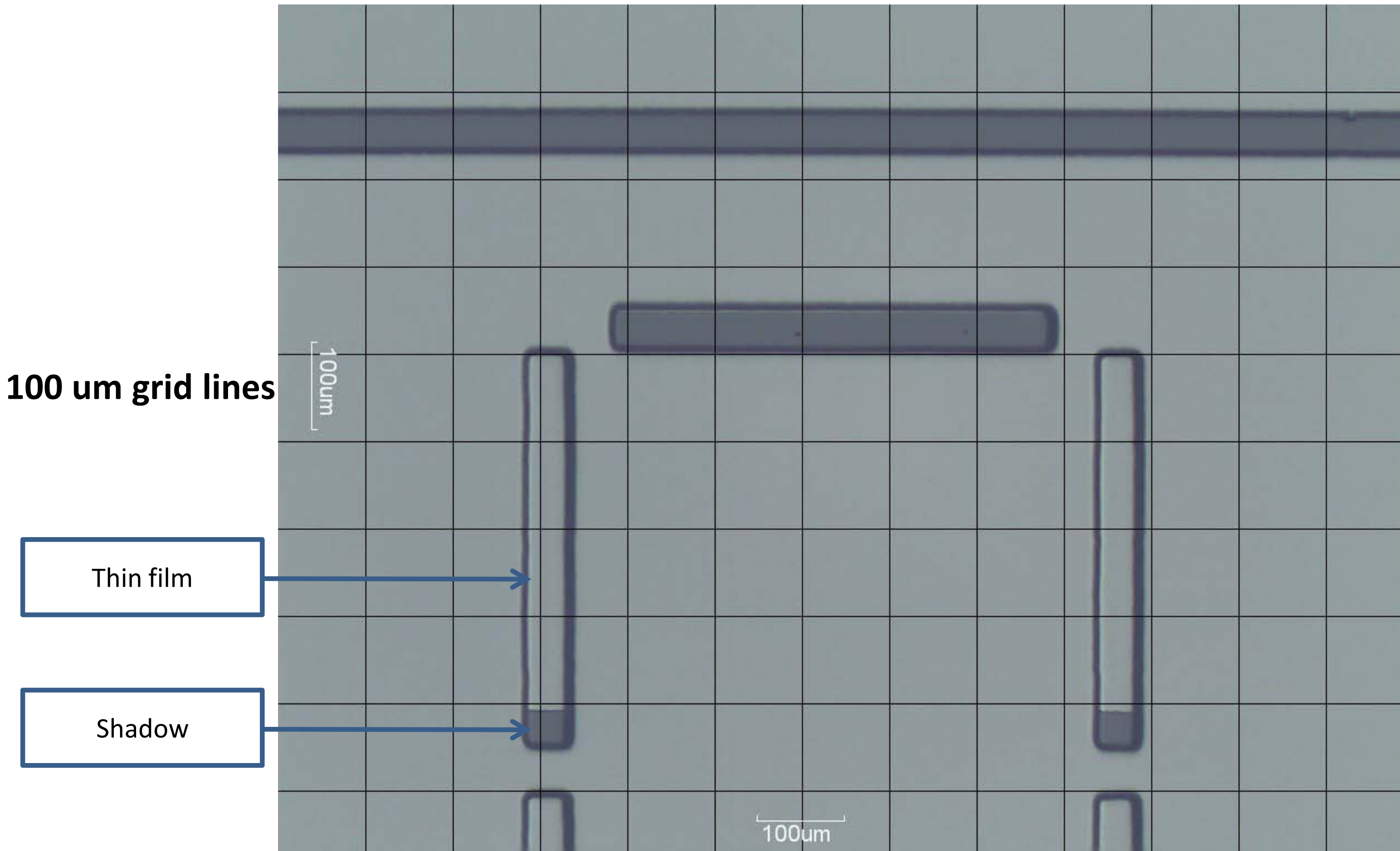
X

½ way down trench

Experimental procedure

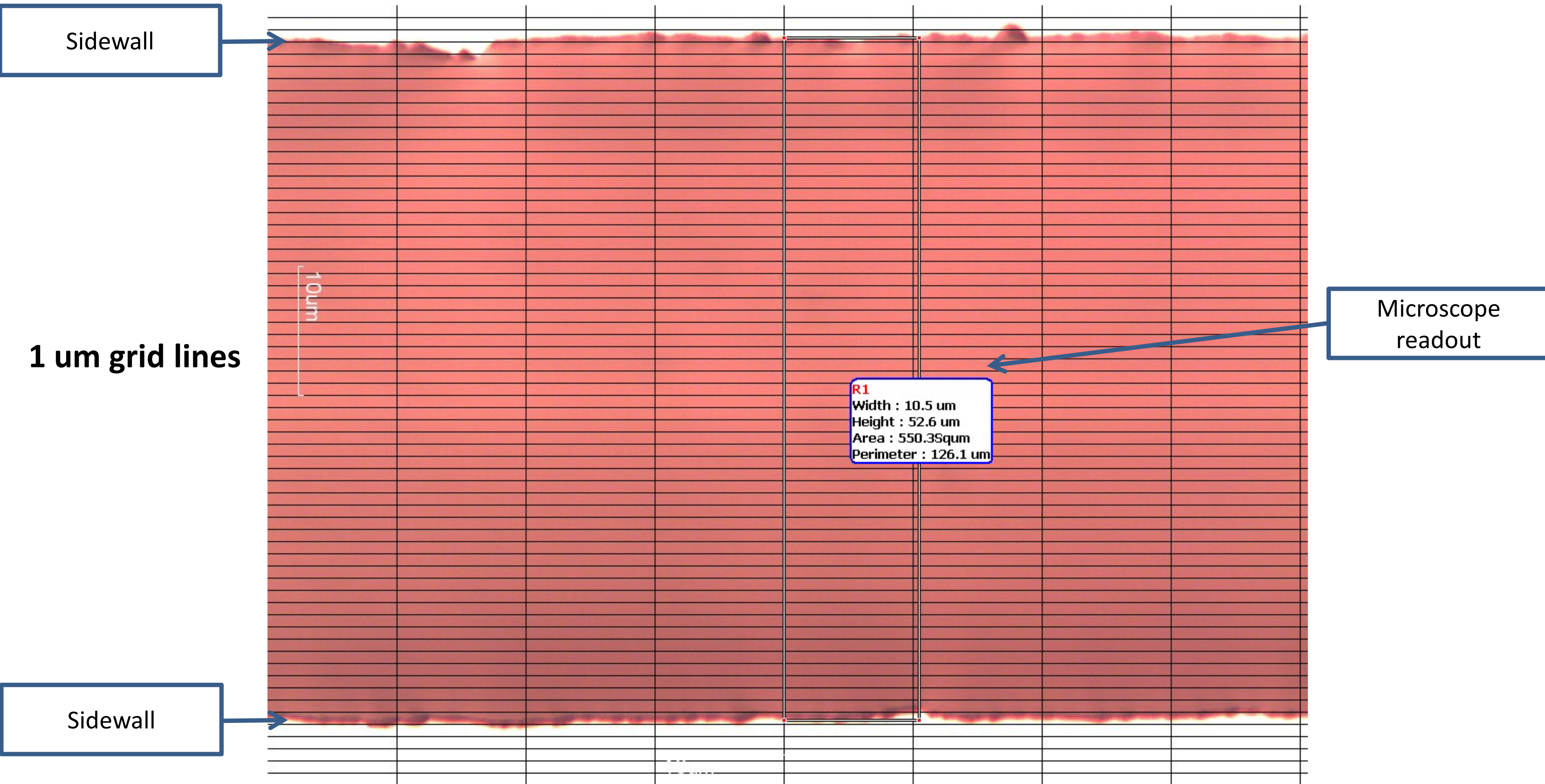
Experiment	Calibration wafer	stsetch	innotec evaporation	innotec tilt jig	innotec assembly/ disassembly	Notes
1	1	50 µm	Al (2000 Å)	45° down	No	Best case
	2	50 µm	Al (2000 Å)	45° down	No	Best case
	3	50 µm	Al (2000 Å)	45° down	No	Best case
2	4	50 µm	Al (2000 Å)	45° down	Yes (tilt only)	Reproducibility & variability
	5	50 µm	Al (2000 Å)	45° down	Yes (tilt only)	Reproducibility & variability
	6	50 µm	Al (2000 Å)	45° down	Yes (tilt only)	Reproducibility & variability
3	2 then 3	50 µm	Al (2000 Å)	Adjusted between runs	No	Test process

Data acquisition



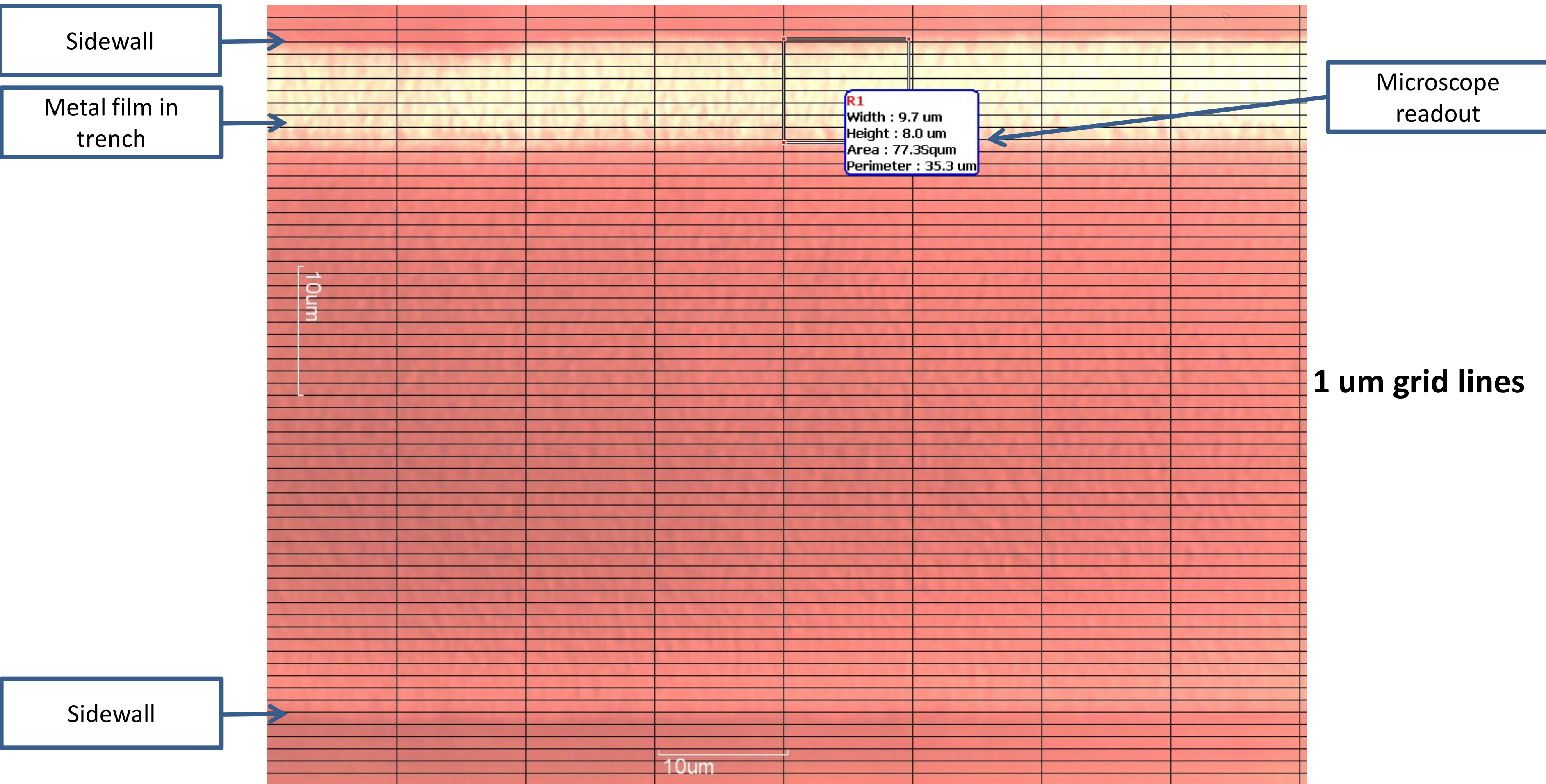
0 tilt line using 5x objective

Data acquisition
(trench width)



0 tilt line using 80x objective
(focus on top, measure trench width)

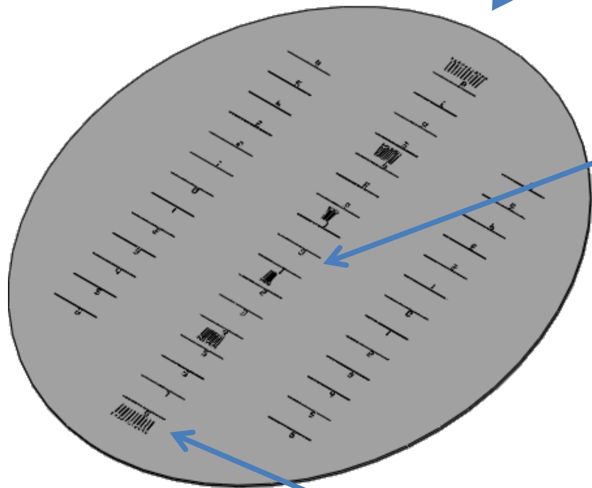
Data acquisition
(thin film width)

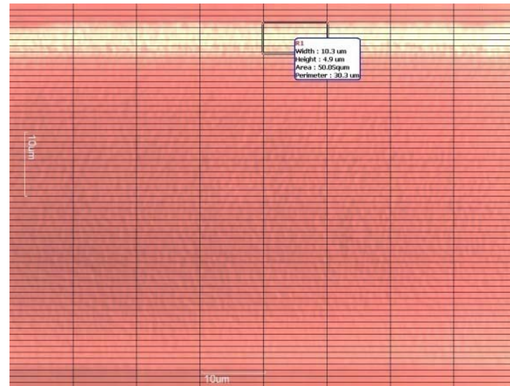


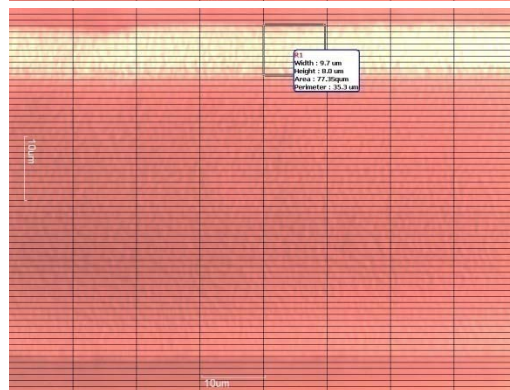
0 tilt line using 80x objective
(focus on bottom, measure width of metallization, x)

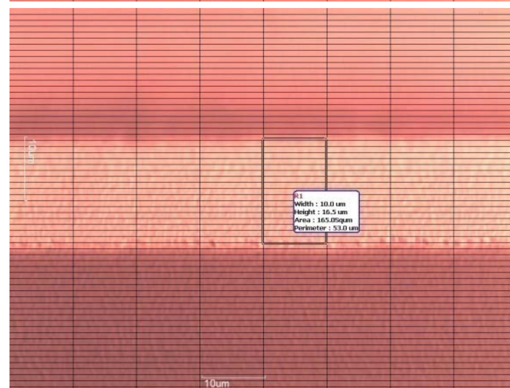
Data acquisition

(top, middle, bottom of wafer)



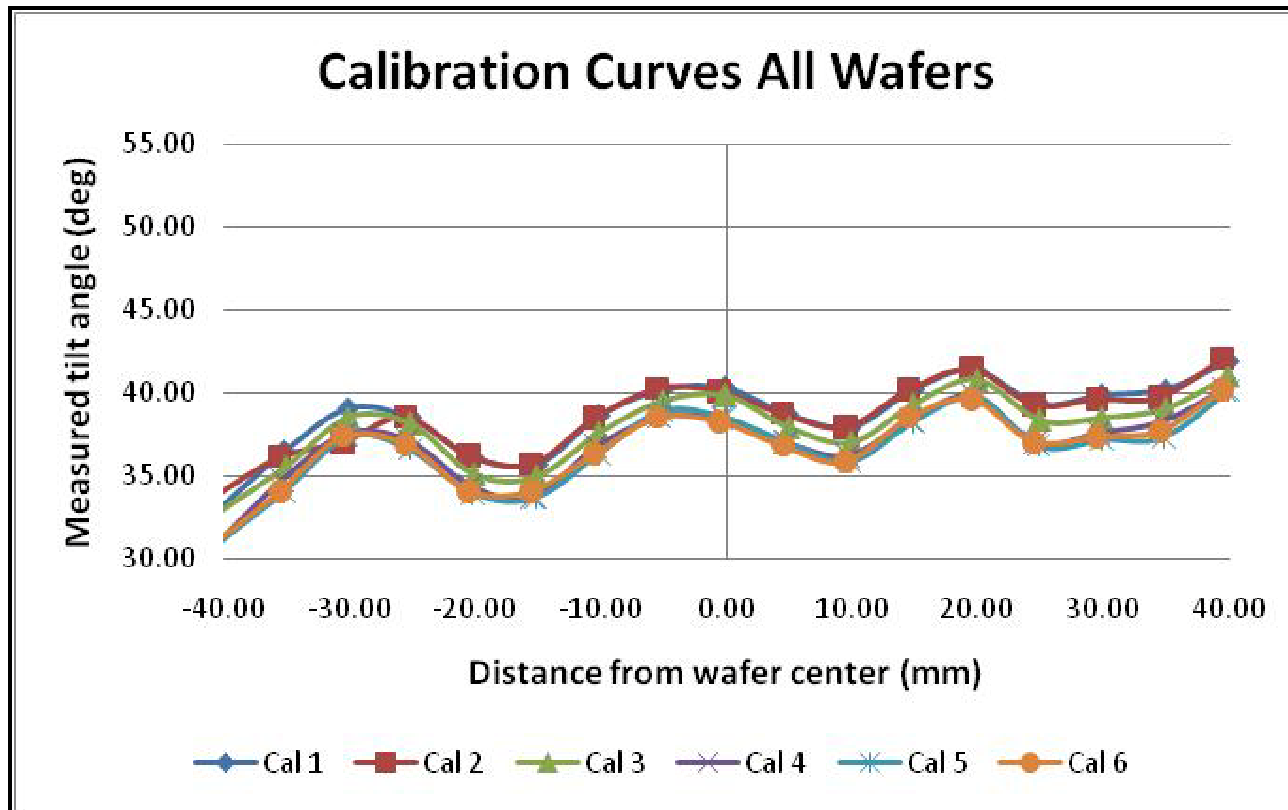






Data analysis

(Preliminary data using nominal trench depth & width)



Data is tight. An odd behavior! But wait! Tilt calculation is dependent on actual trench depth & width!

$$\text{jig tilt} = \text{atan}\left(\frac{\text{trench width} - x}{\text{trench depth}}\right)$$

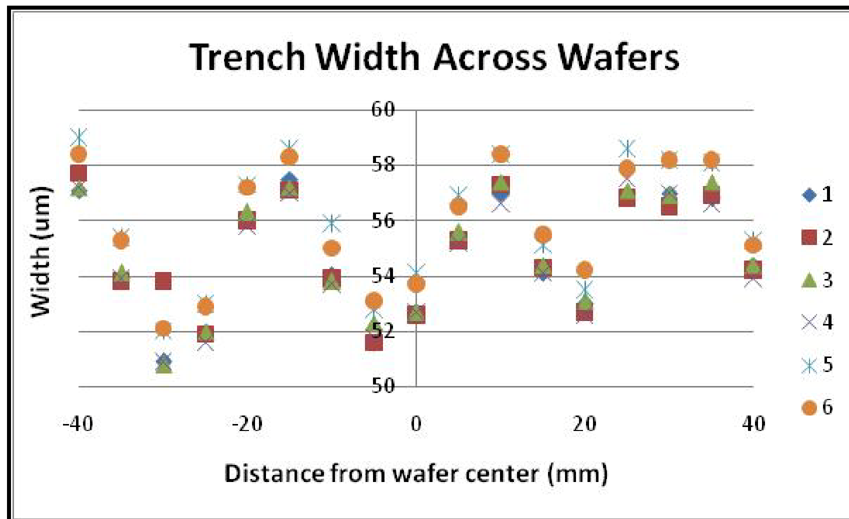
Data analysis
(Measuring trench width)

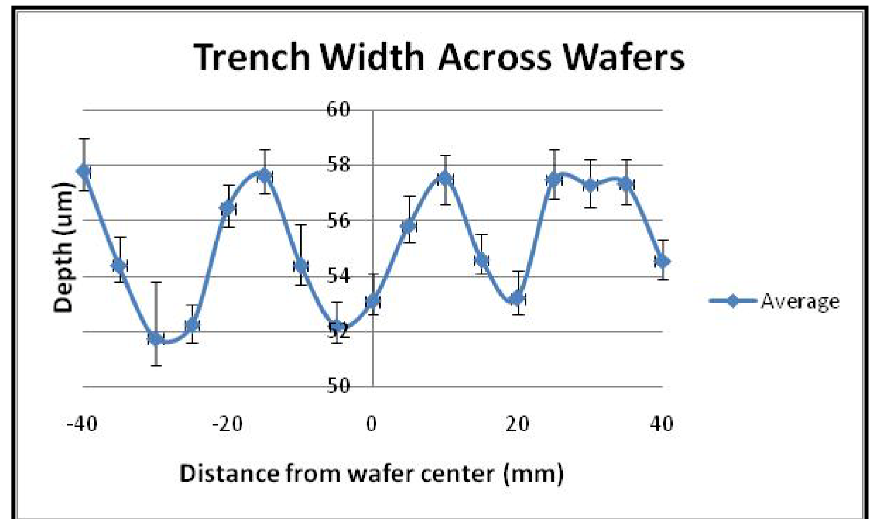
Variability in trench width

(raw data)

Variability in trench width

(min/max around average)

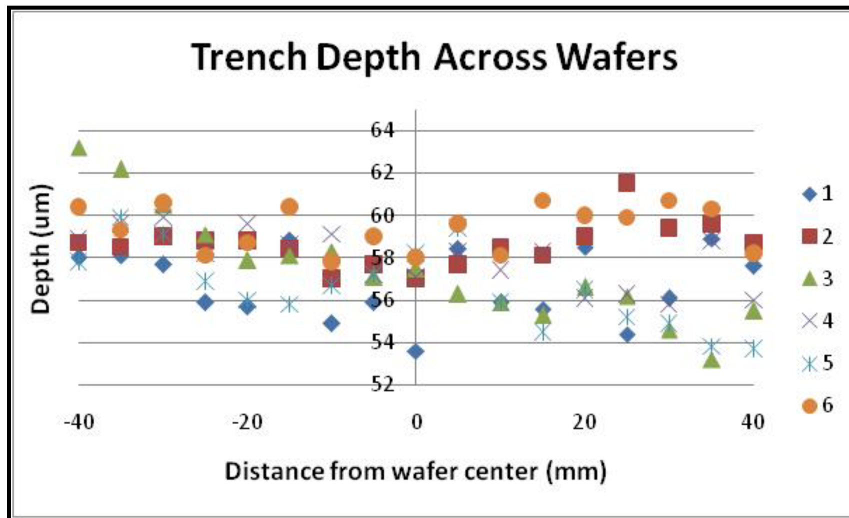




Data analysis
(Measuring trench depth)

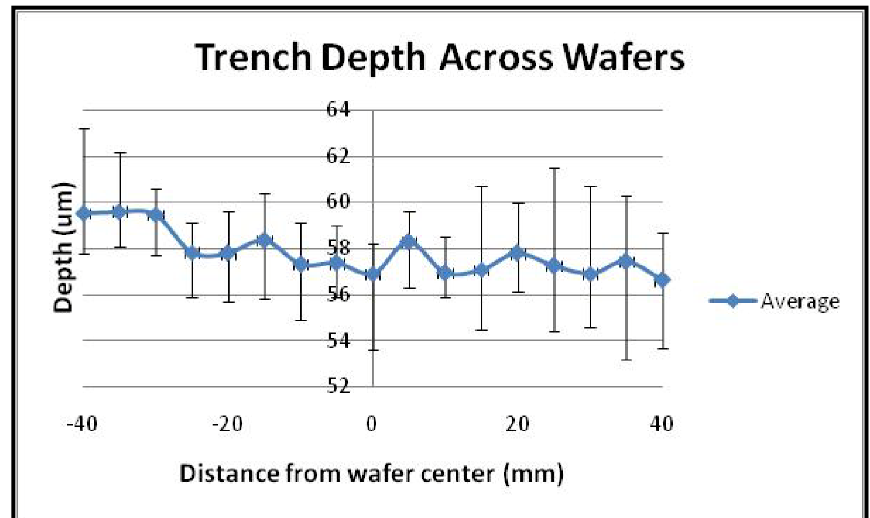
Variability in trench depth

(raw data)



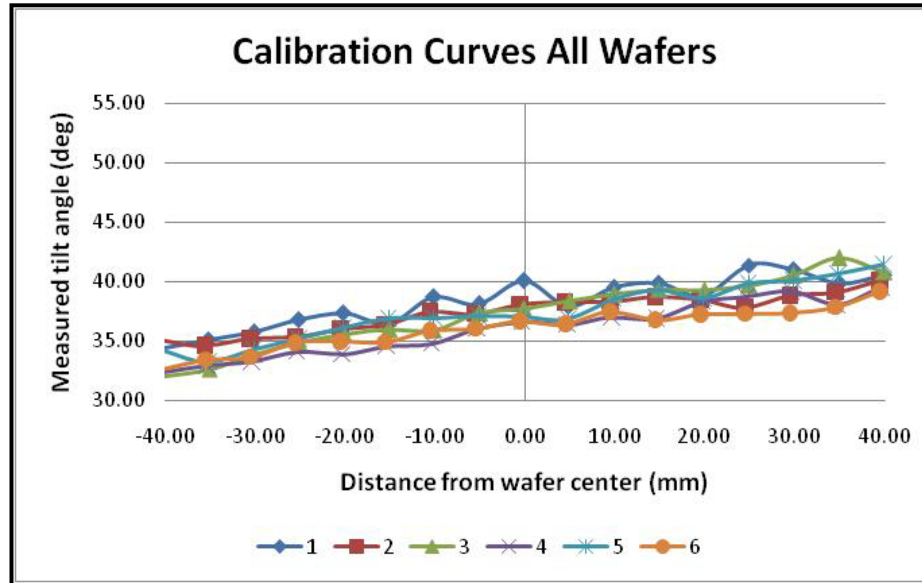
Variability in trench depth

(min/max around average)

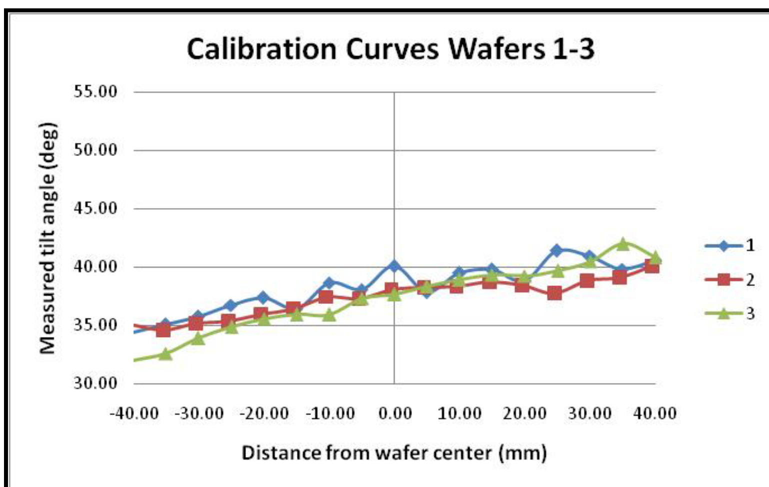


Data analysis

(Data using measured trench depth & width)



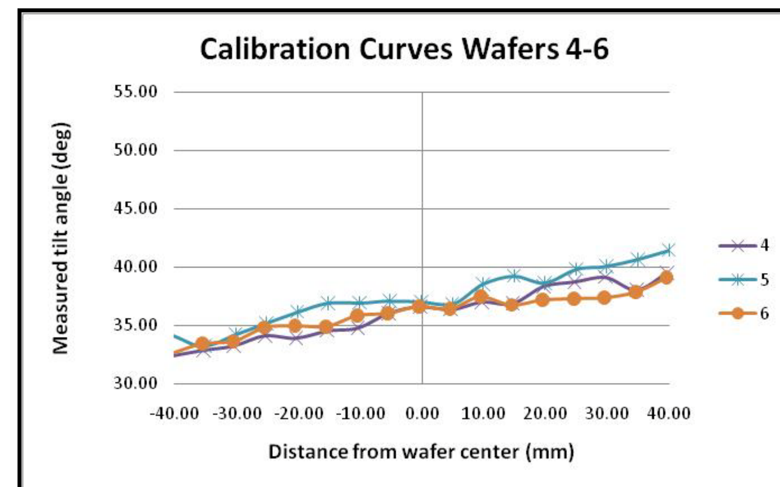
Experiment #1



Root MSE = 0.96 deg

Tilt is reproducible between runs provided the jig is not disassembled.

Experiment #2



Root MSE = 0.86 deg

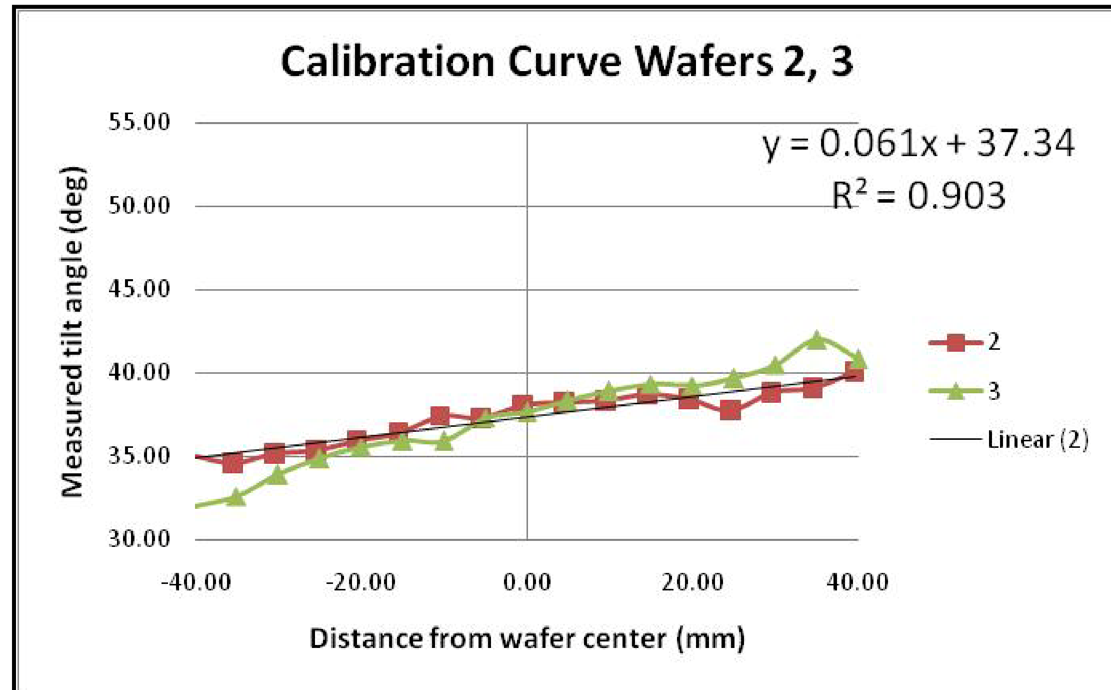
Recommended process to achieve desired tilt

(quick calibration followed by real wafer within 1 innotec reservation window)

1. Set tilt approximately 8 deg less than desired
   - Ensures evaporation in bottom of trench for optical measurement
2. Evaporate calibration wafer on planetary using same slot each time
   - Caution (consider not rotating planetary)
     - Ensure no interference between tilt jig & bell jar hoist during rotation
     - Ensure no interference between tilt jig & quartz crystal during rotation
     - Planetary wobbles during rotation
3. Quickly measure tilt angle using optical microscope
   - Olympus microscope #2 near Headway in Litho
   - Calibrated objectives & measurement tools
4. Develop calibration curve from tilt angle measurements
   - Excel spreadsheet
5. Set tilt jig as appropriate from calibration curve
6. Evaporate real wafer of interest
7. Measure tilt angle achieved

Test run using process
(Experiment #3)

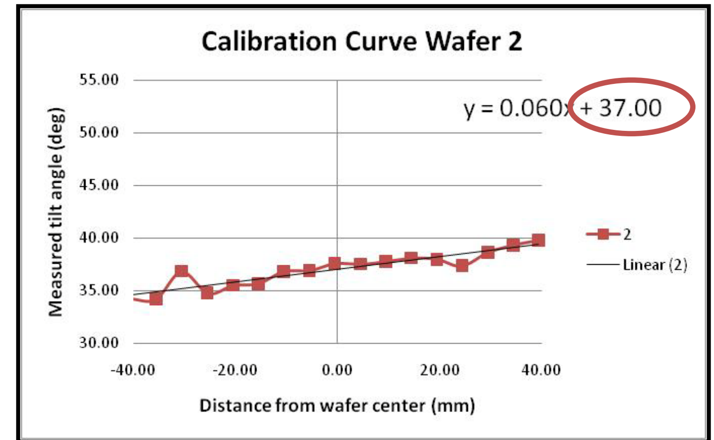
- Selected wafers 2 & 3 for process demo
- Similar curves with ~37 deg crossings at center
- Stripped aluminum
- Ran both wafers during one innotec reservation
  - 2 then 3
- Measured tilt & adjusted accordingly for wafer 3



Experiment #3

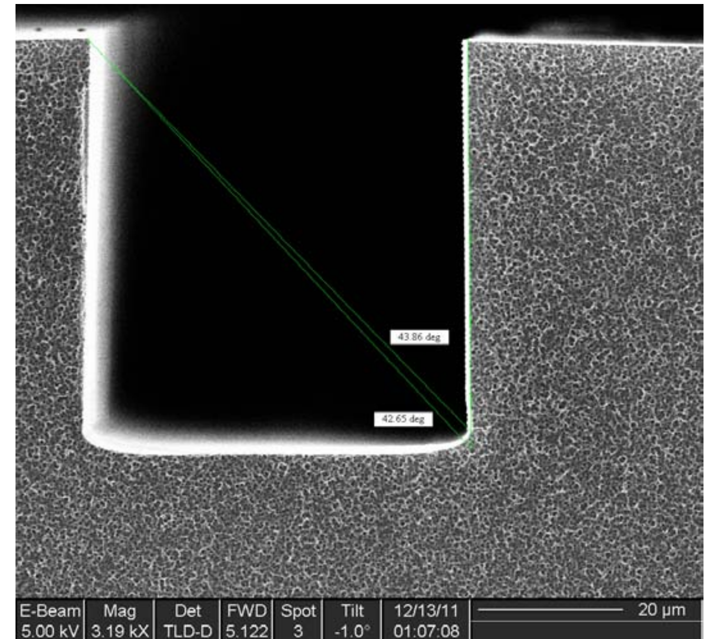
Test run using process
(Experiment #3)

- Evaporated wafer 2
- Generated calibration curve to right during test run (rapid fire!)
- 0 crossing was 37 deg
- Adjusted tilt jig 8 deg down to hit 45 deg



Determination of tilt from wafer 2

- Evaporated wafer 3
- Used SNL's SEM to measure tilt at wafer center (side profile)
- Tilt at wafer center was ~44 deg
- Within ~1 degree of desired



SEM to measure tilt for wafer 3

Summary

- Tilt reproducible if appropriate precautions taken
- Process requires 4 hour innotec reservation window
  - 2 pump downs, each one takes ~1 hour
  - Calibration wafer, then real wafer
  - 30 minutes to develop new calibration curve in between pump downs
- Calibration wafer must be previously characterized for trench width & depth
  - Only metal deposition then need be measured optically
  - Difficult if microscope in use by others
- Pick the right tool
  - Sometimes low tech tools are the most suitable
- Thanks to J & many SNF staff
  - Jeannie, Uli, James, Mahnaz, Nancy