NOVA On-Line CMP Metrology and Its Use for Lot-to-Lot Process Control

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Goals of the NOVA/CMP Project

- Assess the Quality of the NOVA On-Line Metrology Tool
  - Gauge Study
  - Failure Rate
  - Long-Term Stability

- *Implement Basic Run-by-Run Process Control*

Gauge Study Performed to Measure ...

- Variability due to measurement.
- Variability due to pattern recognition.
- Variability due to software wafer alignment.
- Variability due to loading.
- Variability due to slurry.
- Variability due to polishing.

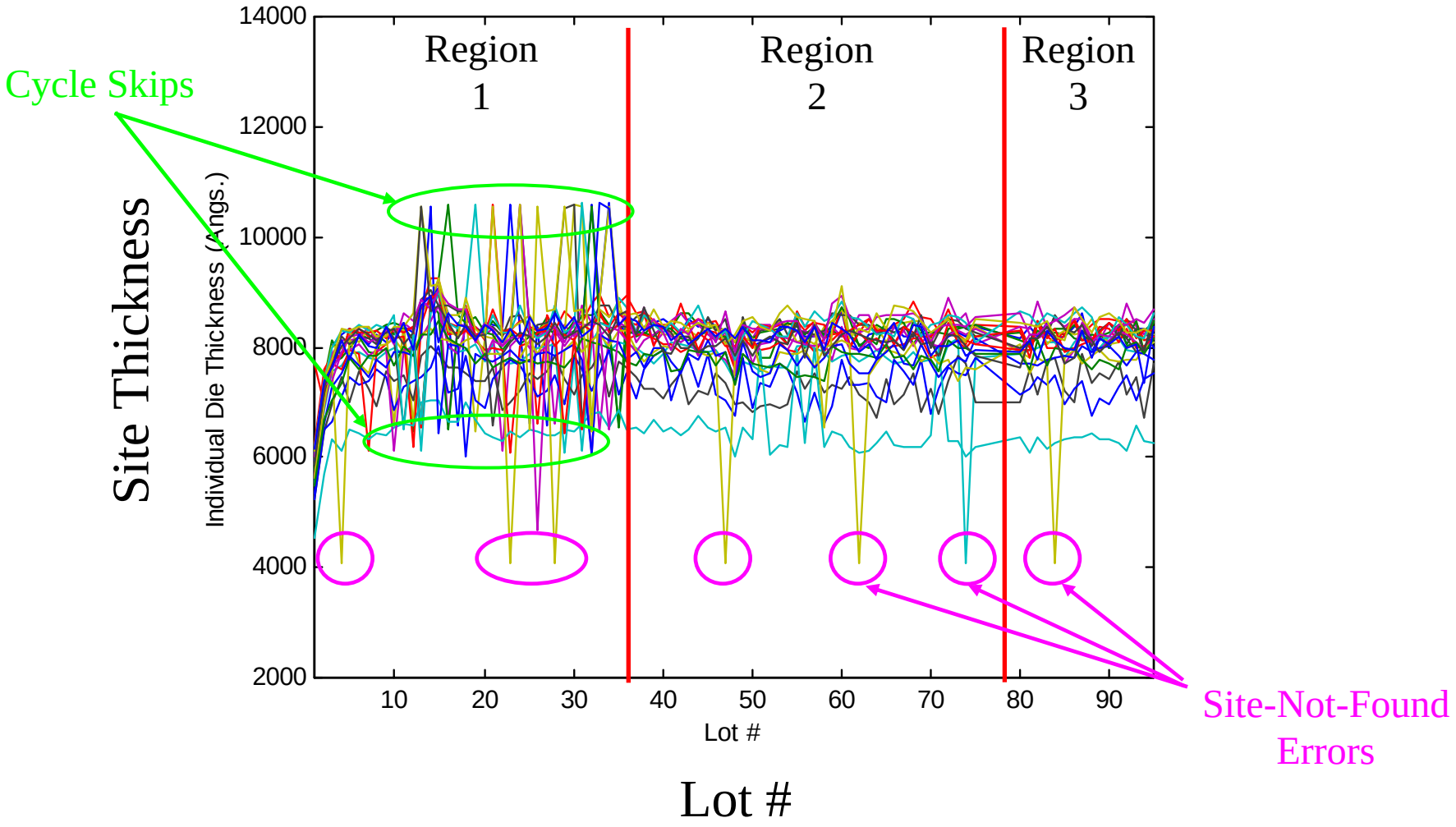
Repeatability Summary

- Measurement Repeatability (Precision)
  - Standard Deviation of 0.5 Ang.
  - Precision metric (std/mean) of 0.006%; *the spec is 0.1%*.
- Pattern Recognition Repeatability
  - Standard Deviation of 4.3 Ang.
  - Precision metric (std/mean) of 0.05%; *the spec is 0.2%*.
- Software Alignment Repeatability
  - Standard Deviation of 8.1 Ang.
  - Precision metric (std/mean) of 0.09%; *the spec is 0.3%*.

Gauge Study Performed to Measure ...

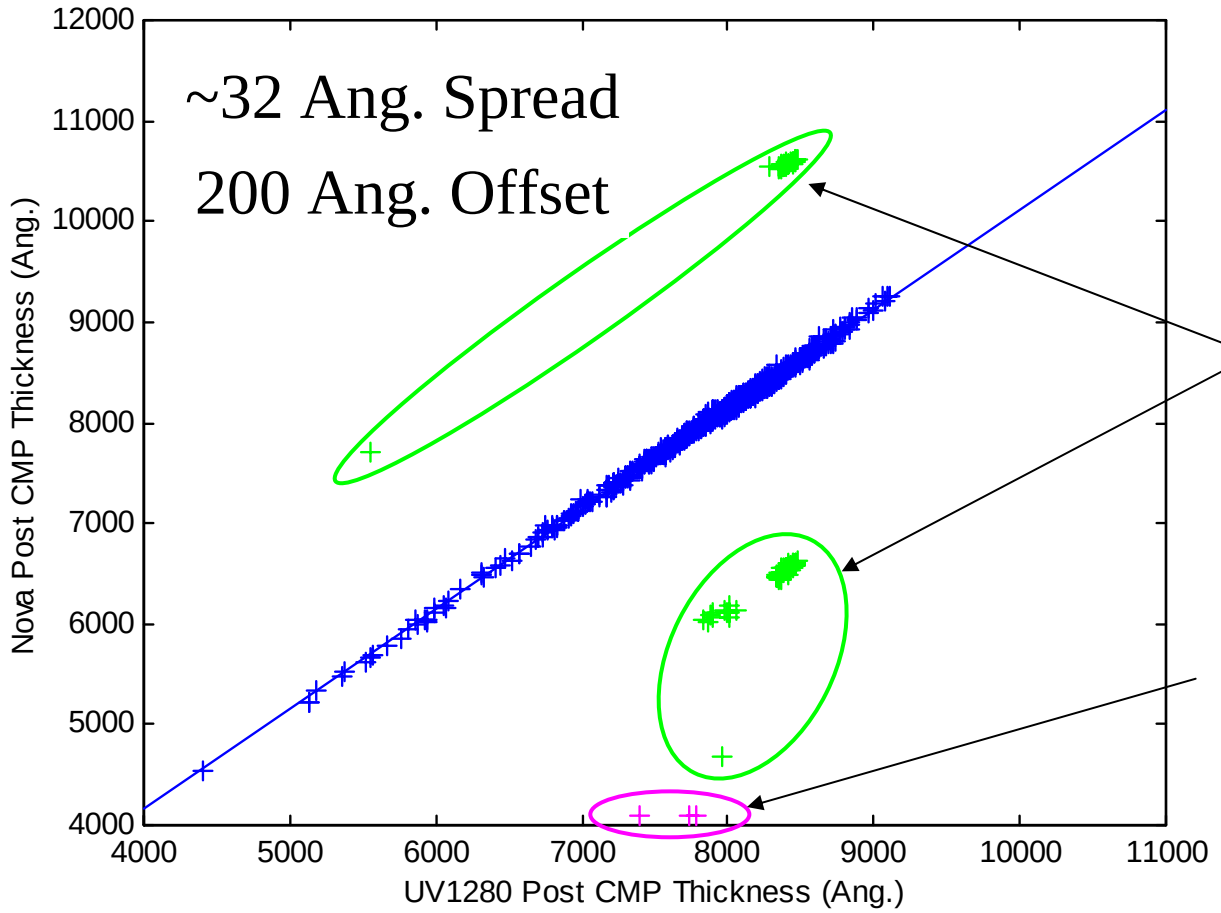
• Variability due to measurement.	▪ 0.5 Angs.
• Variability due to pattern recognition.	▪ 4.3 Angs.
• Variability due to software wafer alignment.	▪ 8.1 Angs.
• Variability due to loading.	▪ ?
• Variability due to slurry.	▪ ?
• Variability due to polishing.	▪ ?
• Spread at Pre-Polish	▪ 12 Angs.
• Spread due to Cleaning	▪ 8 Angs.
• Spread at Post-Polish	▪ 30 Angs.
• Variability due to loading+slurry+processing	➔ 10 Angs.

NOVA Post-Polish Thickness (Patterned Wafers)



Pre-Clean Nova vs. Post-Clean UV1280 (Region 1, Beginning)

NOVA
83%
Success Rate



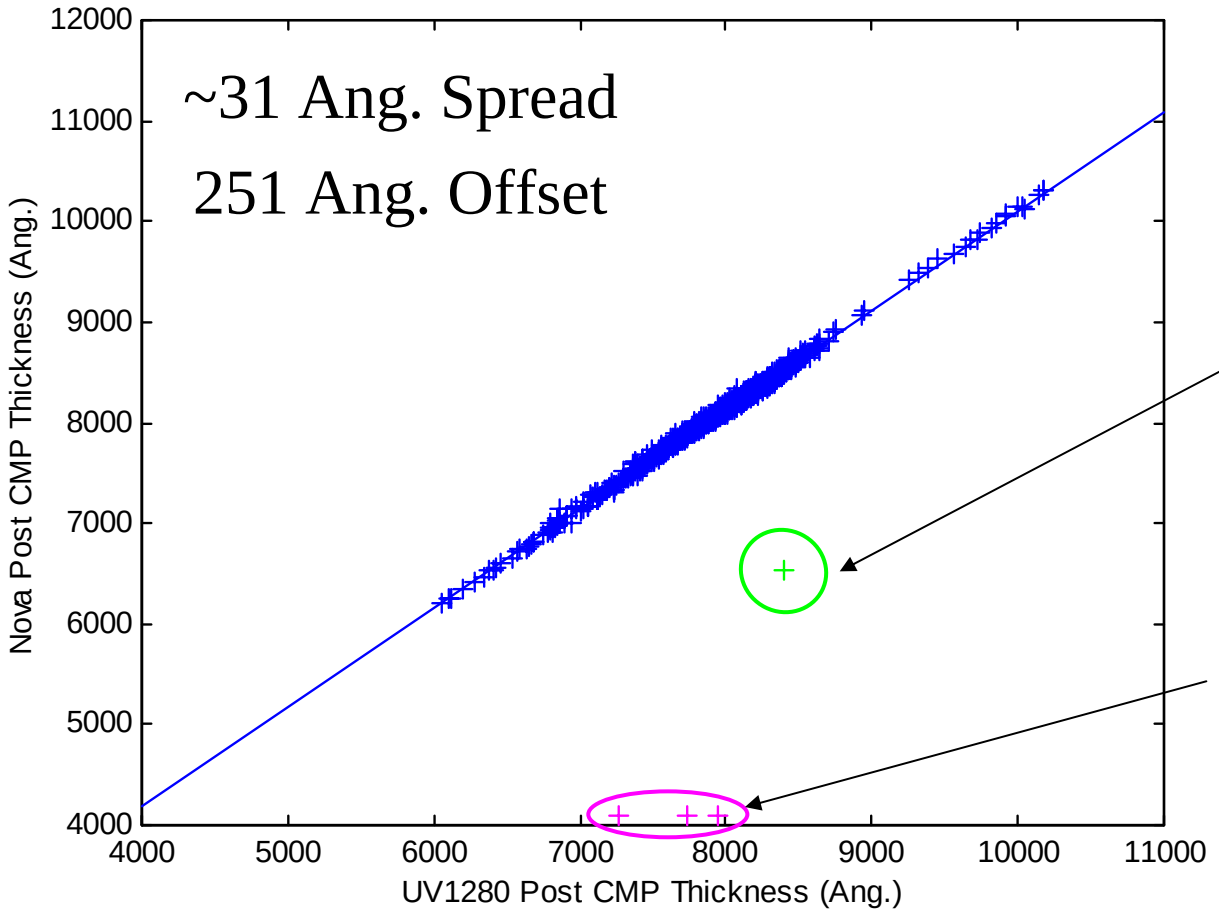
65 NOVA
Cycle Skips

3 NOVA
Site-Not-Found
Errors

UV1280
100% Success Rate

Pre-Clean Nova vs. Post-Clean UV1280 (Region 2, After Bounds on NOVA Tightened)

NOVA
99%
Success Rate



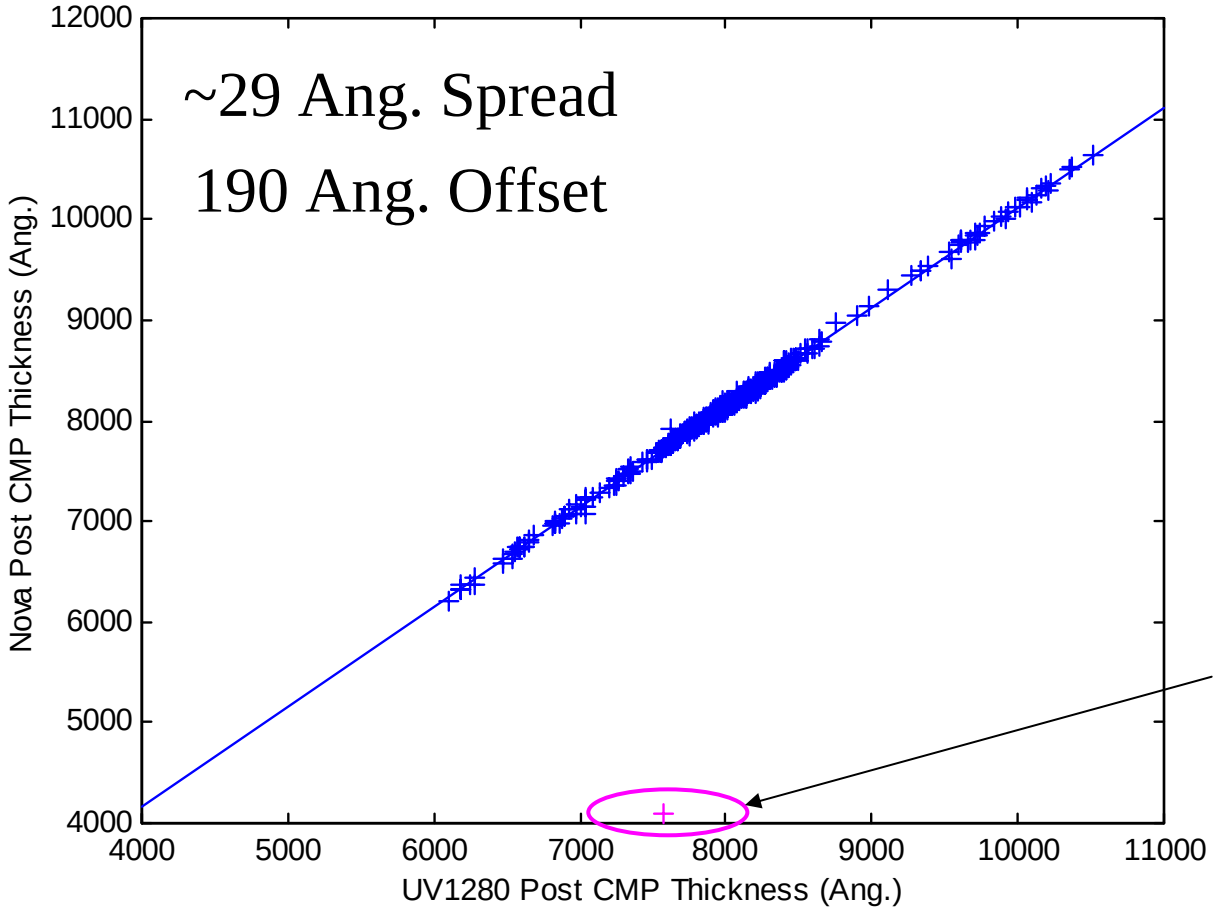
1 NOVA
Cycle Skips

3 NOVA
Site-Not-Found
Errors

UV1280
100% Success Rate

Pre-Clean Nova vs. Post-Clean UV1280 (Region 3, Bounds Re-opened & Algorithm Changed)

NOVA
99.5%
Success Rate



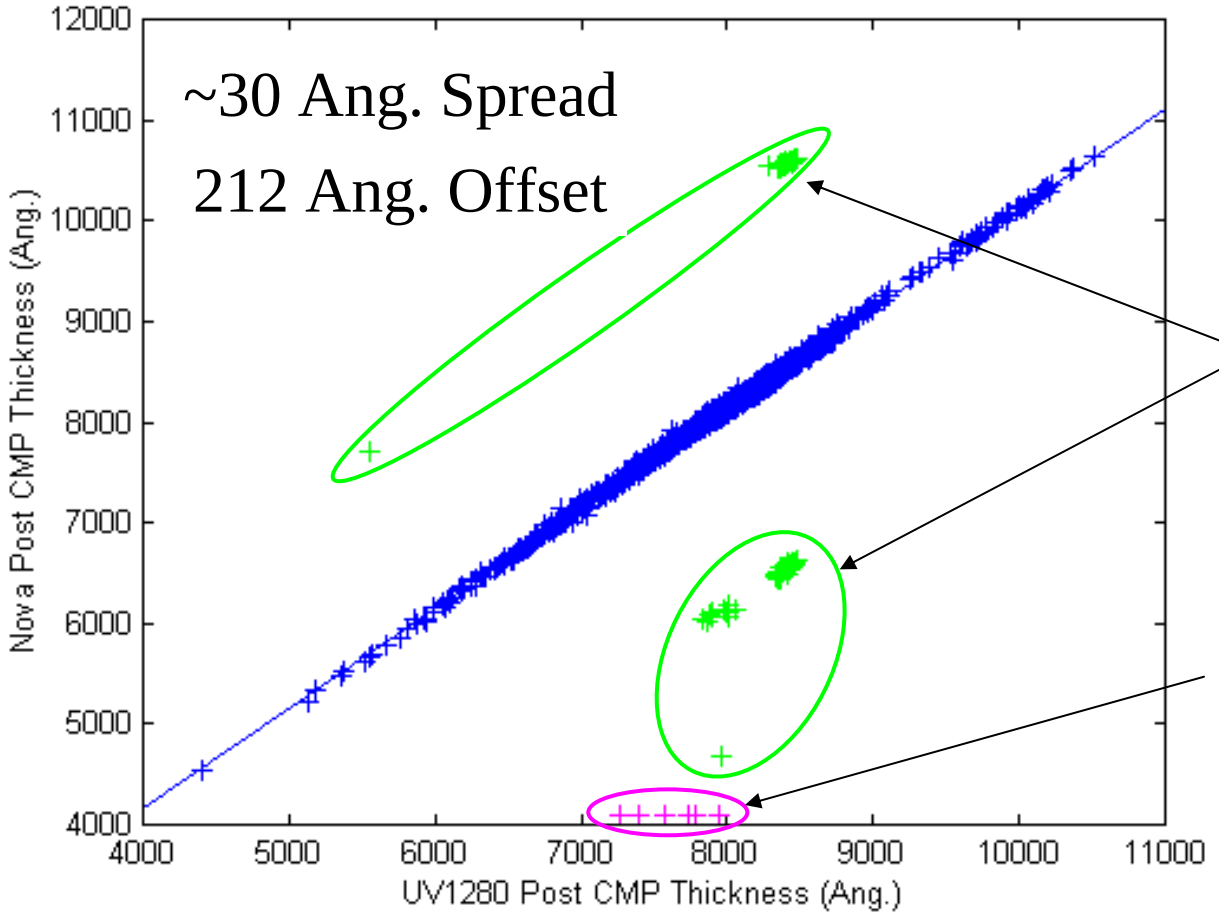
0 NOVA
Cycle Skips

1 NOVA
Site-Not-Found
Errors

UV1280
100% Success Rate

Pre-Clean Nova vs. Post-Clean UV1280 (Polished Patterned Wafers Overall)

NOVA
93%
Success Rate



66 NOVA
Cycle Skips

7 NOVA
Site-Not-Found
Errors

UV1280
100% Success Rate

Goals of the NOVA/CMP Project

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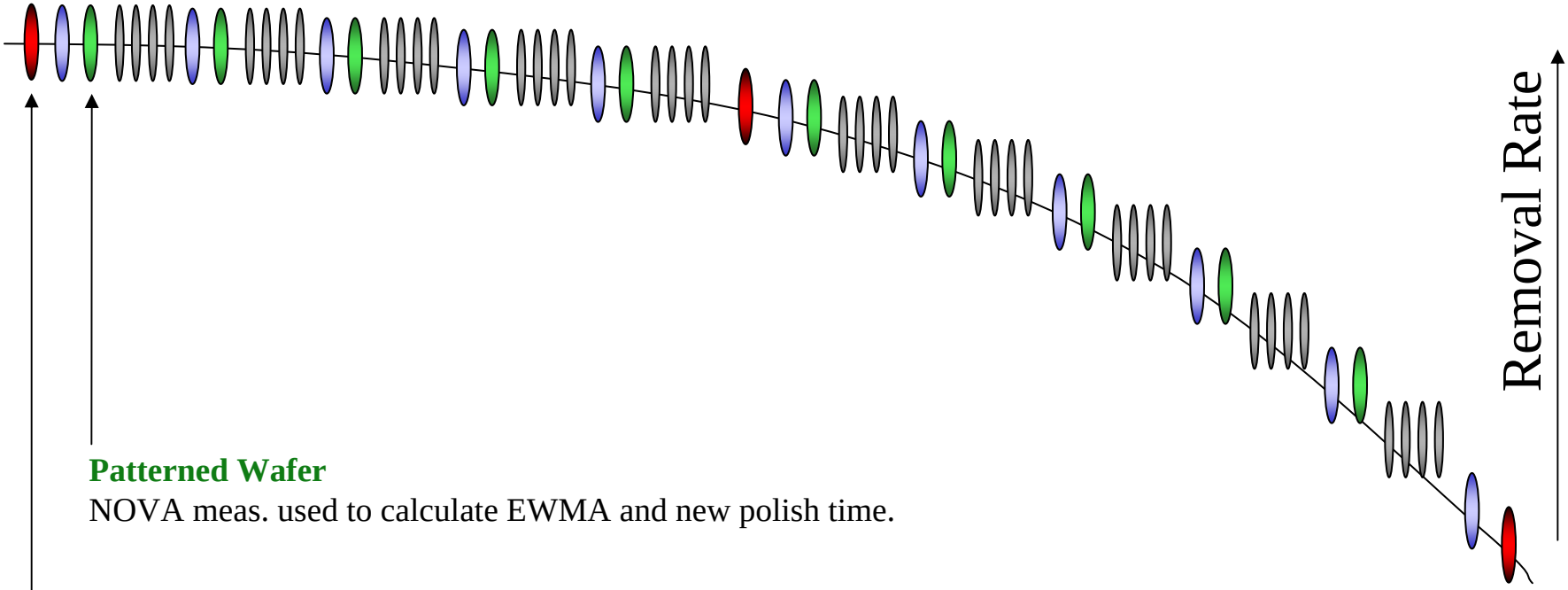
  - Gauge Study
  - Failure Rate
  - Long-Term Stability

- *Implement Basic Run-by-Run Process Control*

Run by Run Control Experiment Plan

Blanket Pilot Wafer
Used to monitor particles, uniformity, and to calculate the blanket wafer-level polish rate to verify MIT model.



Patterned Wafer
NOVA meas. used to calculate EWMA and new polish time.

MIT Patterned Wafer
Measured ex-situ.
Used to study the planarization length over the life of a CMP pad..

Reliability Testing Summary

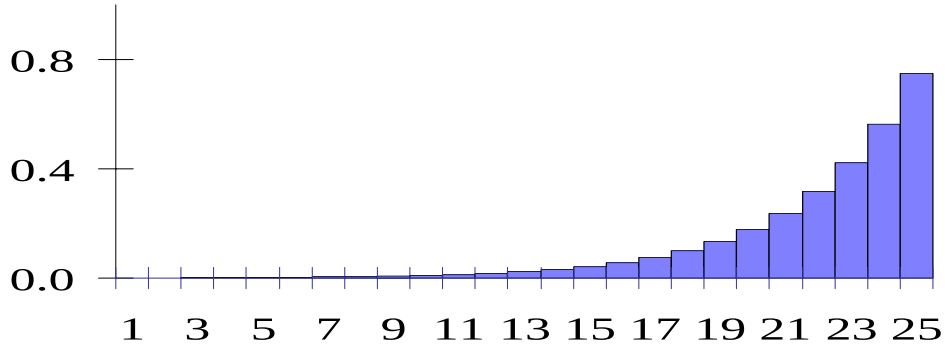
- 99% wafer alignment success rate
  - 1 failure in 96 wafer loads.
- 99.7% site measurement success rate
  - 7 site not found errors in 2112 measurements.
- NOVA System froze 2 times in 600 wafers over three days
  - tries to keep measuring after wafer unloads,
  - reboot takes less than 5 minutes.
- NOVA Wafer Handler Controller failed 1 time
  - restart takes about 30 seconds.

Offset Between NOVA and UV1280

- Offset = Average of (NOVA - UV1280)
- Offset at Pre-Polish
  - 47 Angs.
- Offset from Cleaning
  - -137 Angs.
- Offset at Post-Polish
  - -212 Angs.
- Unknown Effects
  - → -100 Angs.
  - Higher cleaning due to surface damage is known (Discussion with Greg Hames)
  - This number seems consistent with these results
  - Need to verify this measuring pre- and post- on NOVA
  - Determine if this offset is a function of the device

EWMA Rate Estimation

- Calculate an Exponentially Weighted Moving Average (EWMA) of previously measured rates

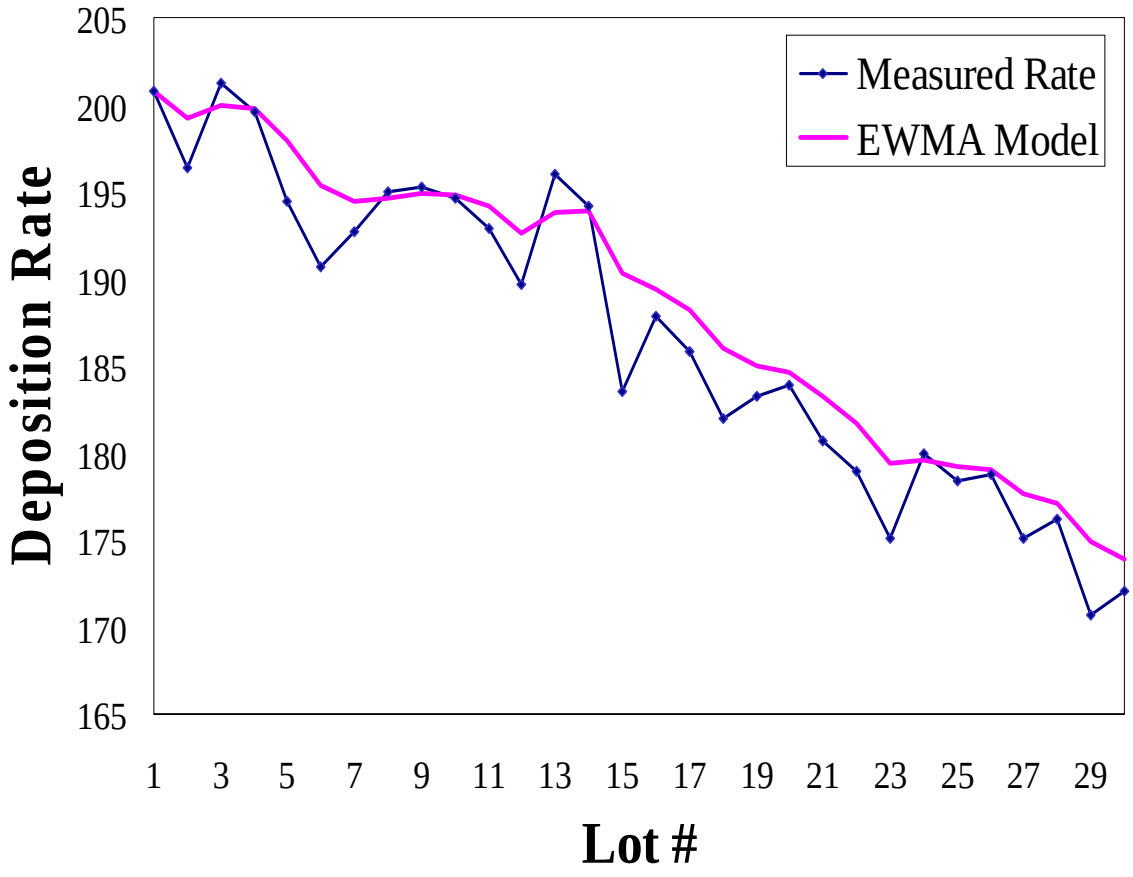


$$Rate_{EWMA}[n] = w \bullet Rate_{Measured}[n] + (1-w) \bullet Rate_{EWMA}[n-1]$$

- The higher ***w***, the more recent values are weighted.
- The weight is chosen based on how noisy the process is.

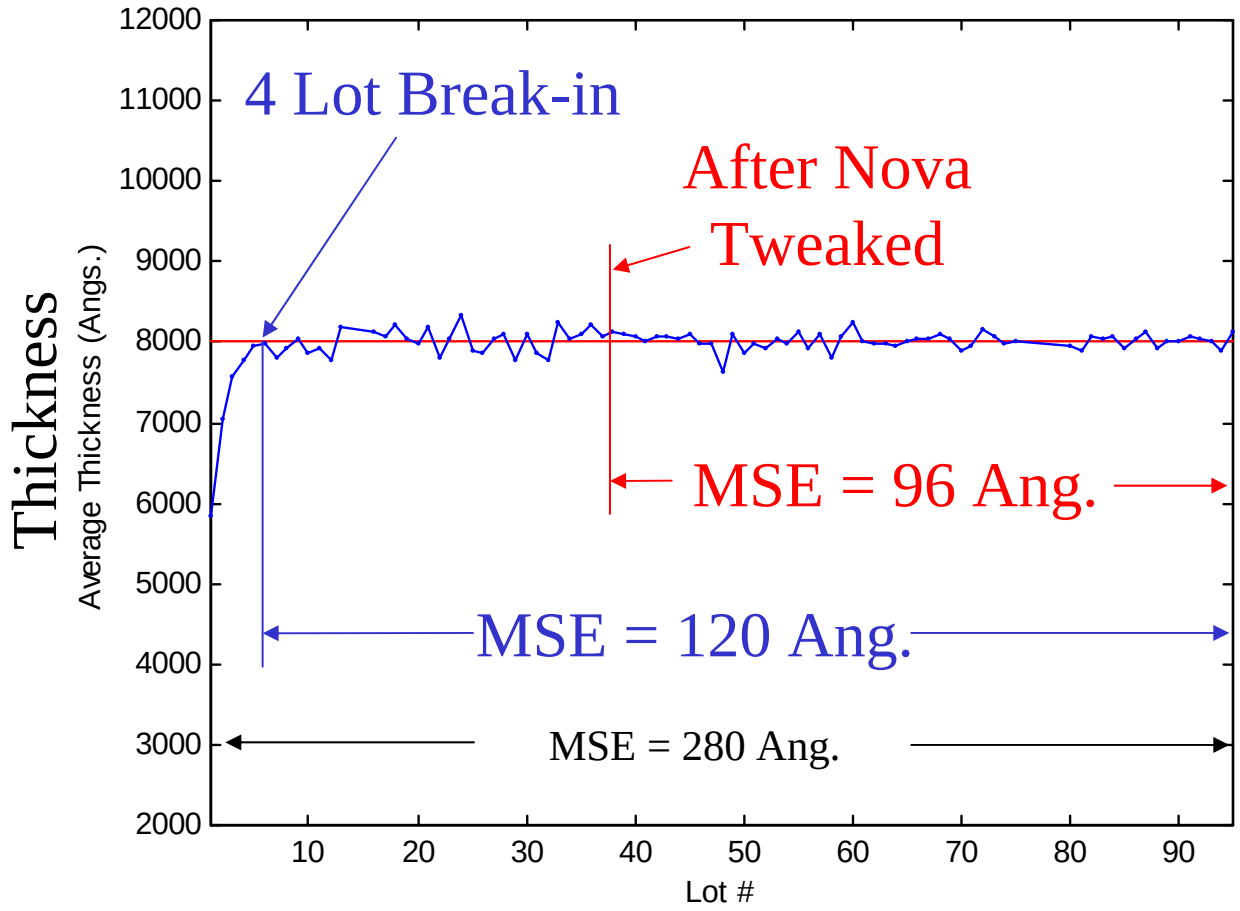
EWMA Rate Estimation

Estimate the rate to determine the process time.



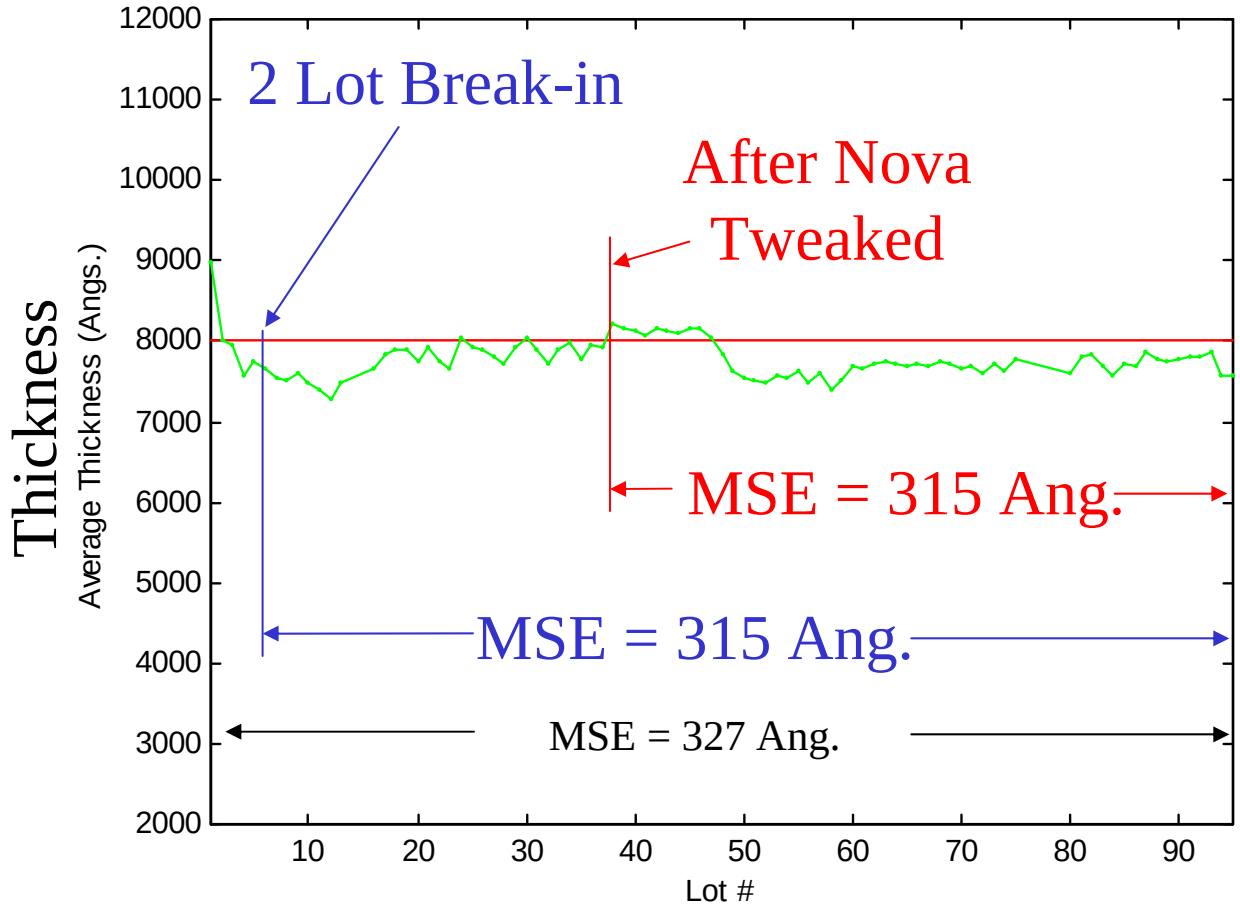
See T. Smith and J. Stefani TAR on Control of Metal Sputter Deposition

Controlled Average Thickness (Polished Patterned Wafers)



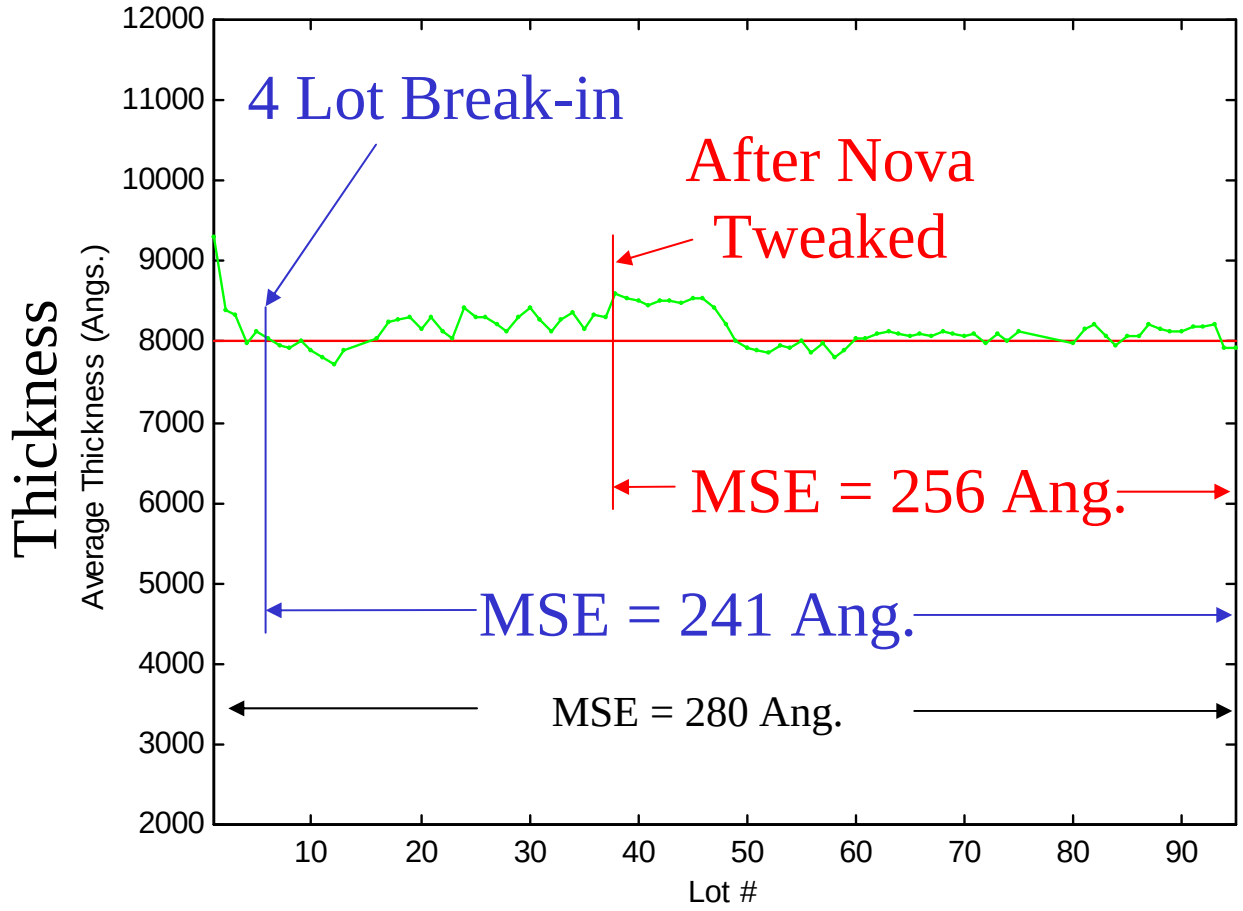
Lot #

Uncontrolled Average Thickness (Polished Patterned Wafers)



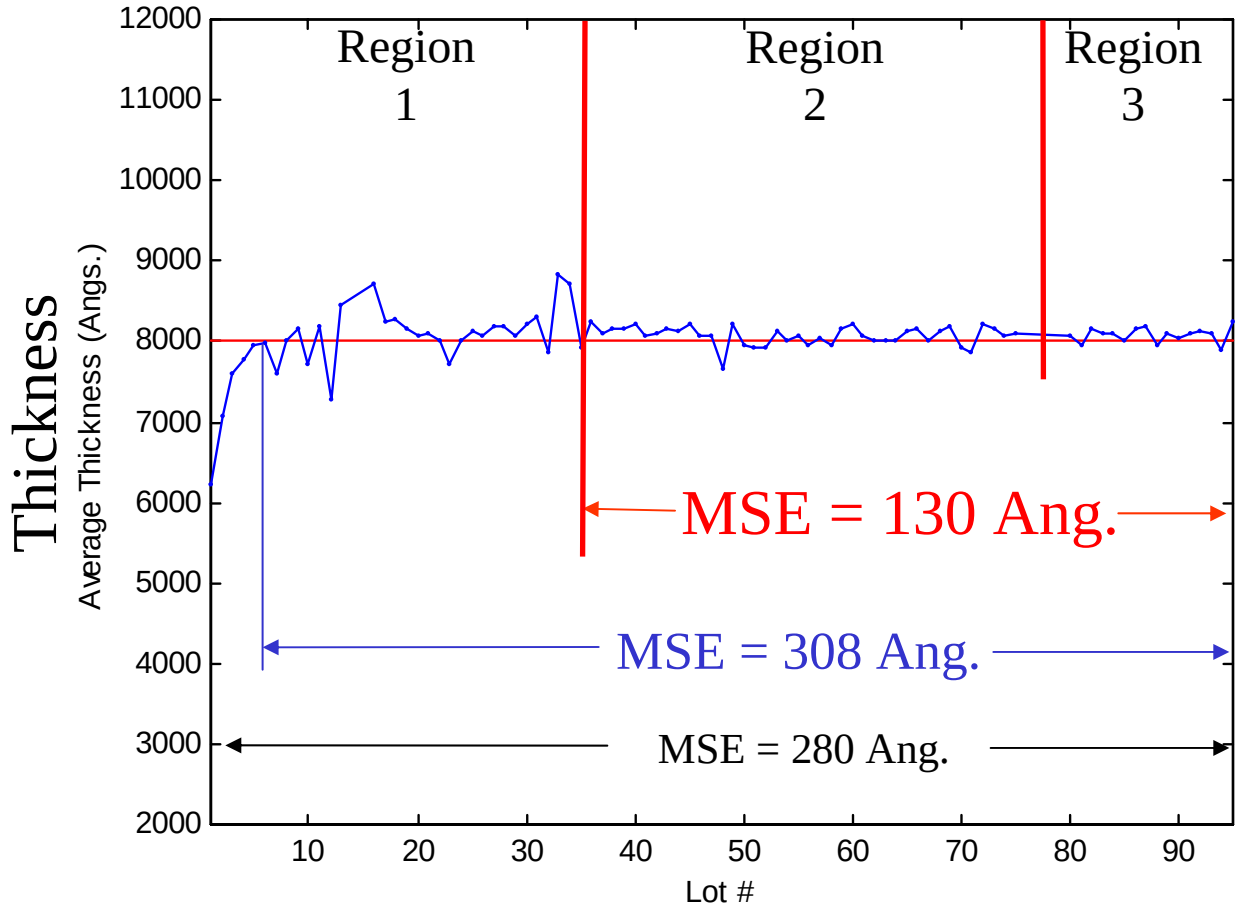
Lot #

Uncontrolled Average Thickness (Polished Patterned Wafers)



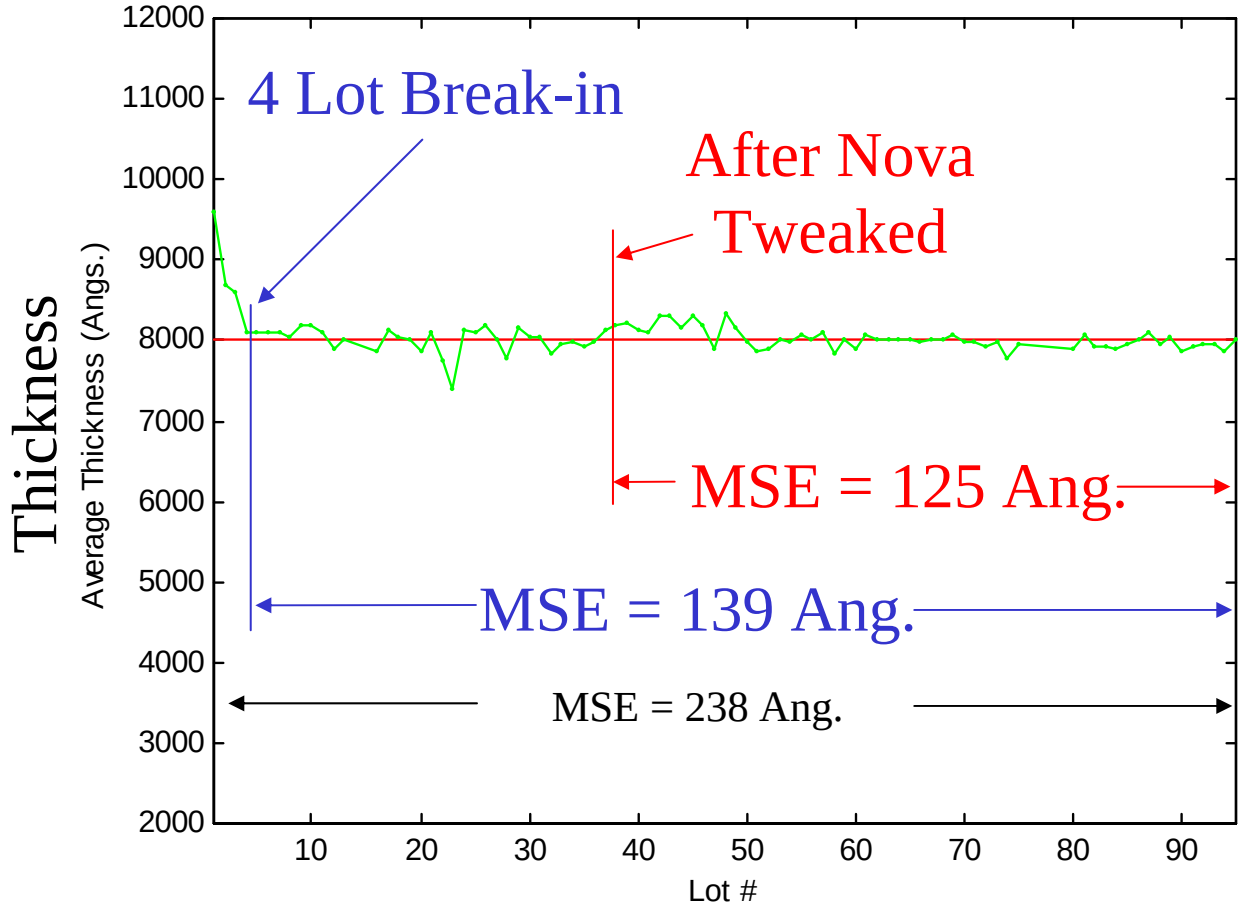
Lot #

Controlled Average Thickness (5 Sites on Polished Patterned Wafers)



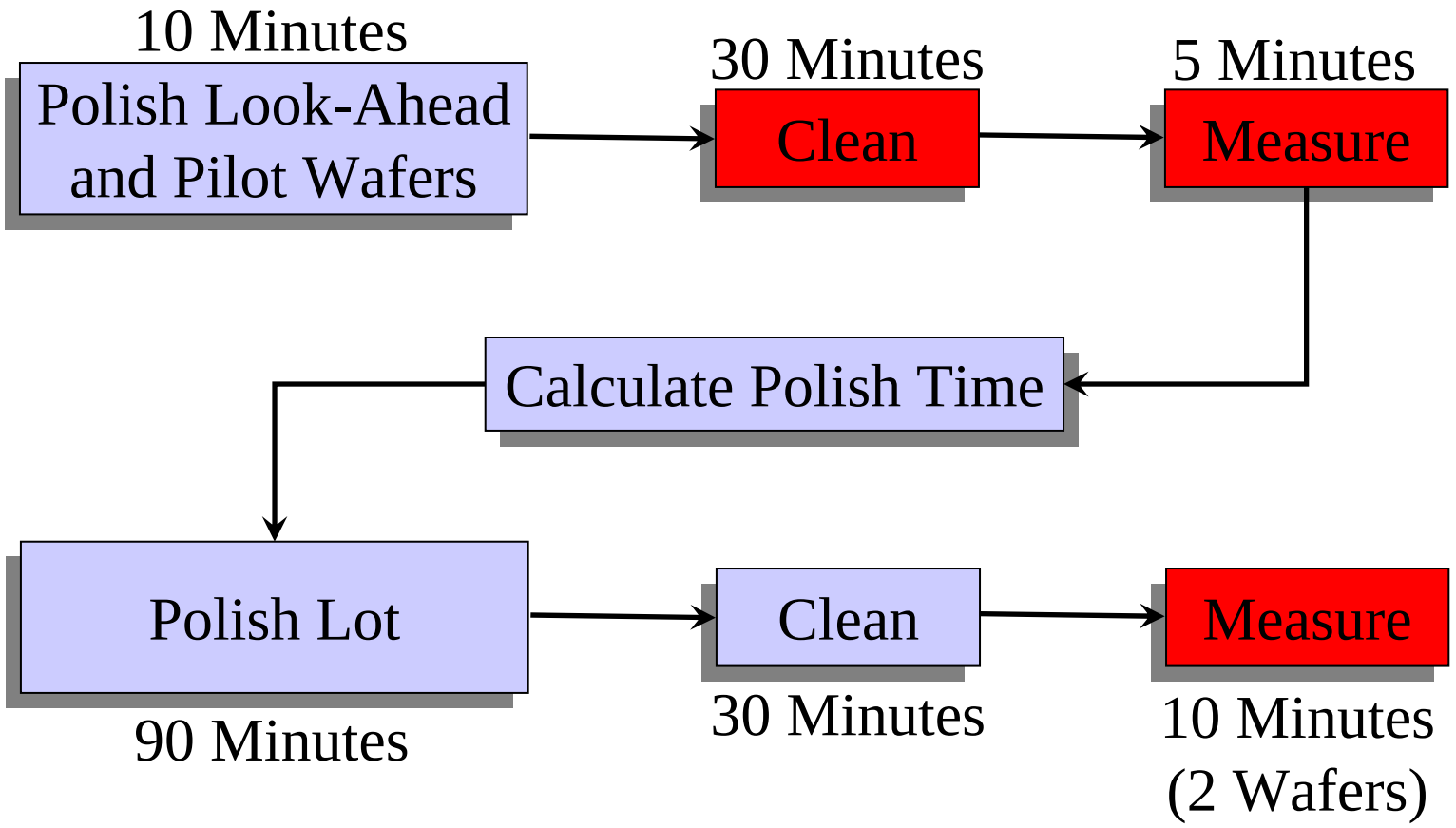
Lot #

Using Pilot Wafers with SFE to Control Average Patterned Wafer Thickness



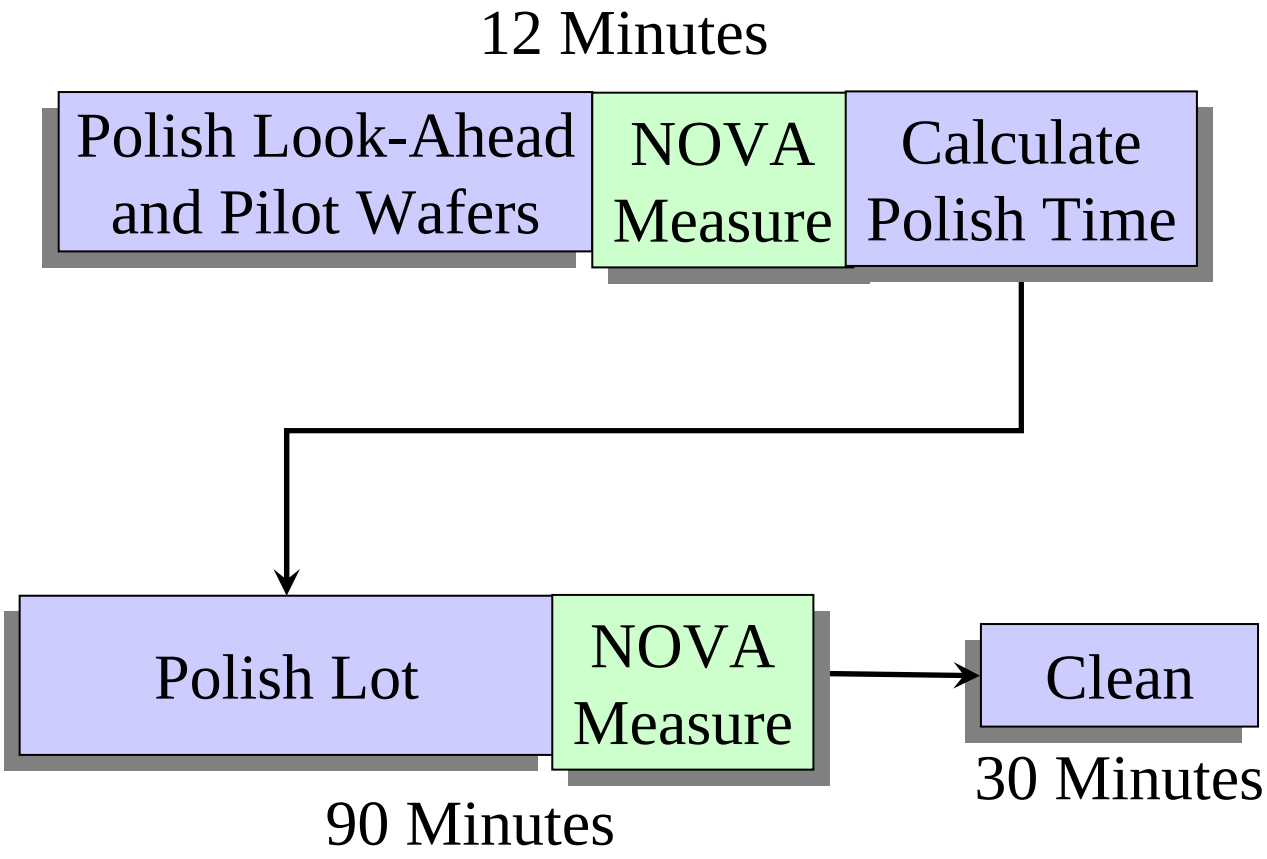
Lot #

CMP *Without* NOVA and RbR Control



Total Time (Best Case): 2 Hours 55 Minutes

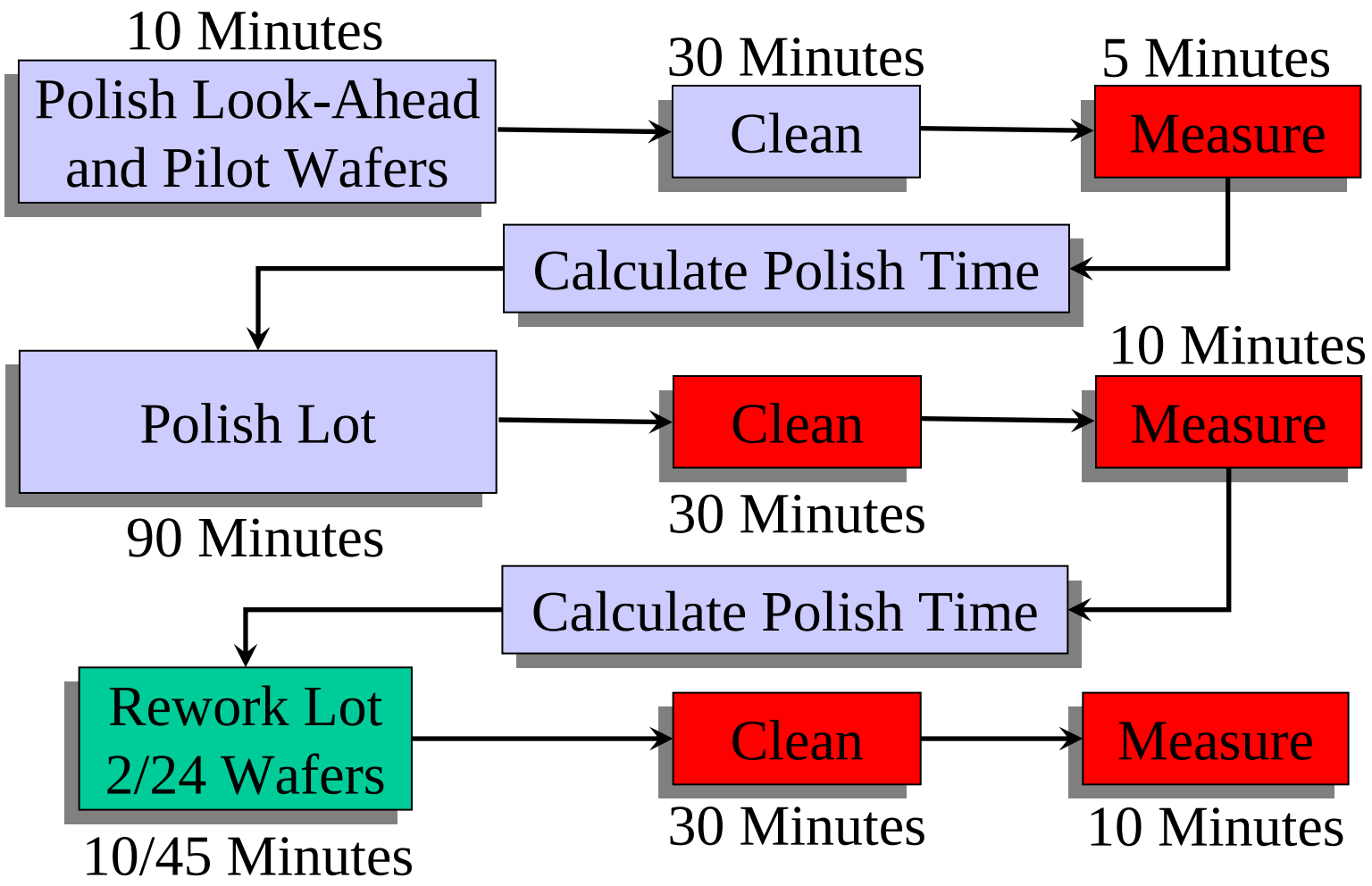
CMP *With* NOVA and RbR Control



Total Time (Simplest Case): 2 Hours 6 Minutes

25% Improvement

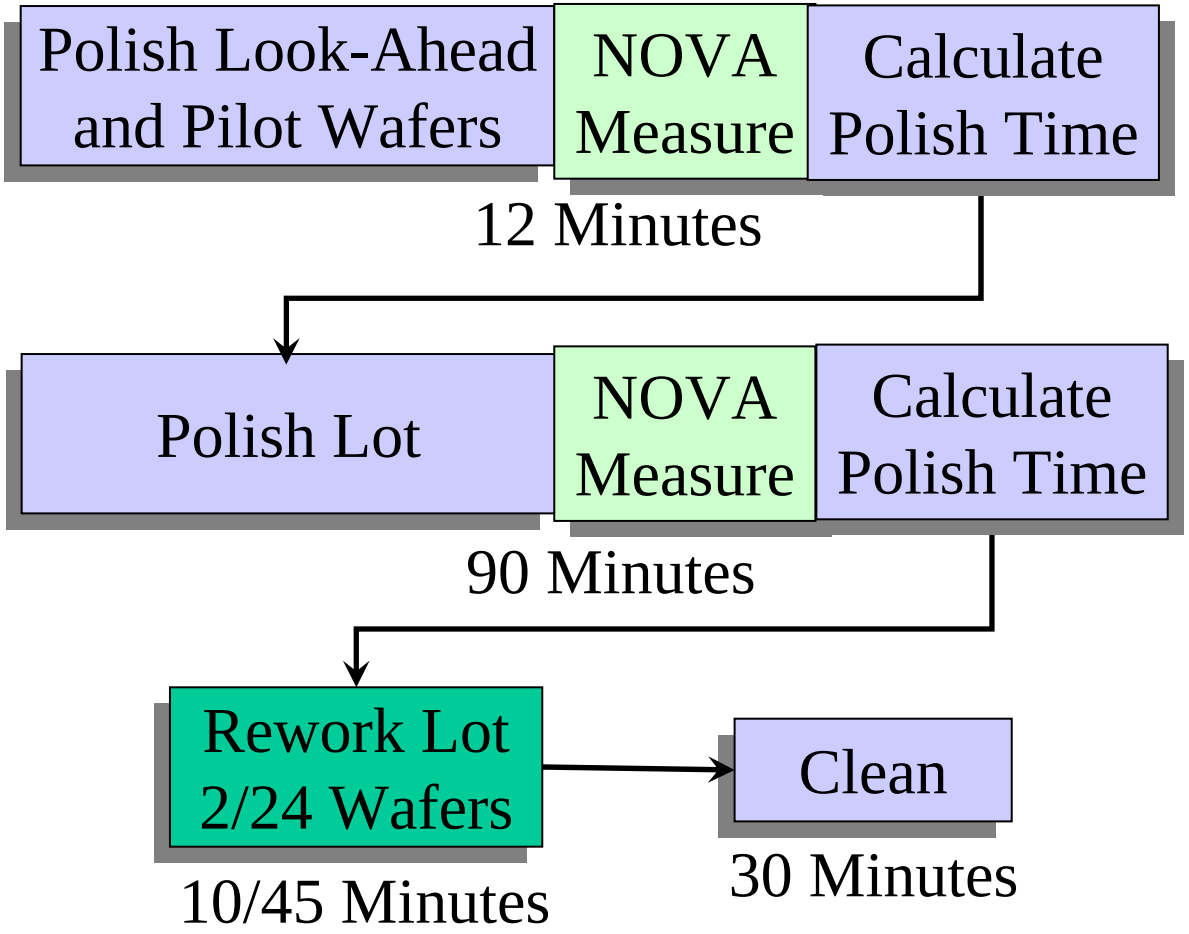
CMP *Without* NOVA and RbR Control



Total Time (2 Wafer Rework): 3 Hours 45 Minutes

Total Time (24 Wafer Rework): 4 Hours 20 Minutes

CMP *With* NOVA and RbR Control



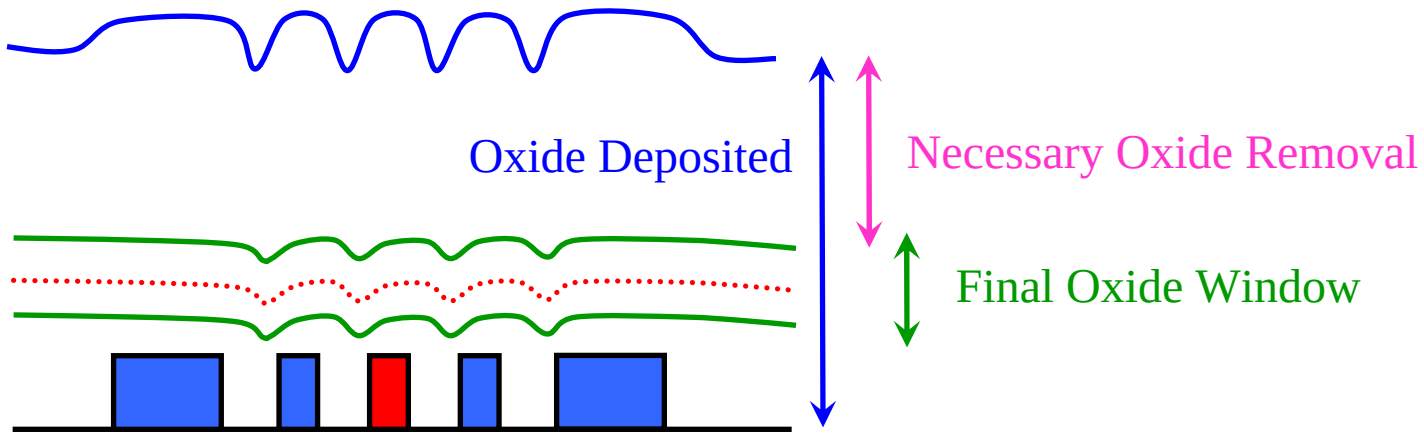
Total Time (2 Wafer Rework): 2 Hours 22 Minutes (37%)
Total Time (24 Wafer Rework): 2 Hours 55 Minutes (32%)

Throughput, COO, and Waste Savings

- Throughput increases of up to 37%.
- Water and peroxide savings of up to 66%.

- Reduced Cost Of Ownership (COO) due to throughput of up to 31%.
- Reduced COO for future facilitation of up to 66%
- Reduced COO due to less ex-situ metrology tools.

COO Savings Due to Improved Quality



- Oxide Deposited = Removal + Window
- Better process control means a smaller window
- A smaller window means less deposited oxide
- Less deposition
  - Higher deposition throughput
  - Less chemical usage
  - Less waste from chamber cleans

Current Conclusions

- The precision, repeatability, and reliability of the NOVA are very good.
- Nova and UV1280 correlate within ~30 Ang.
- Simple EWMA control of patterned wafers using the NOVA results in an average thickness error of 96 Angs.
- This control is a 70% improvement of fixed-time polishing, and a 23% improvement over control using blanket pilots and sheet film equivalents.
- 25-37% increase in throughput.
- Reduced Cost Of Ownership
  - Less cleaning, higher throughput, fewer ex-situ metrology tools, and improved process control