Model-Based Profile Control for 200mm CMP: Easier than 300mm CMP or Not?

Dick de Roover, Abbas Emami-Naeini, Jon L. Ebert, La Moyne Porter II,
Jamie Leighton‡, Andrew Cockburn‡

Email: roover@scsolutions.com

SC Solutions, Inc.
1261 Oakmead Pkwy
Sunnyvale, CA 94085

‡Applied Materials
974 E. Arques Ave.
Sunnyvale, CA 94086

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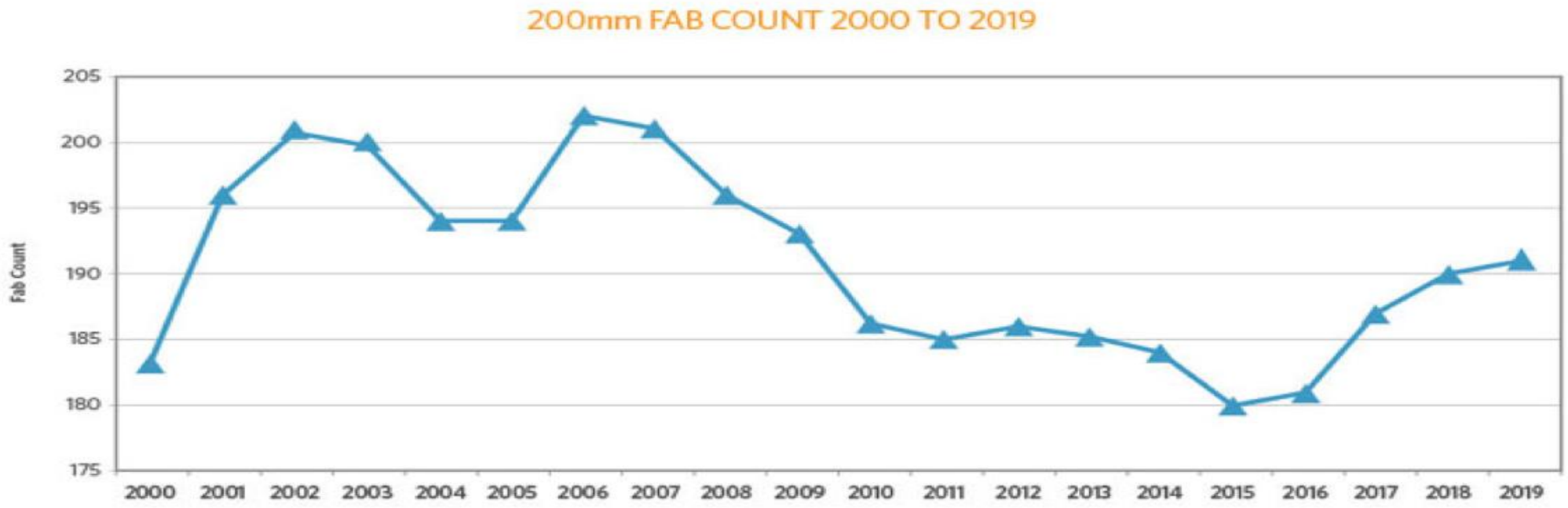
Overview

- **Introduction & Motivation**
- **Real-time Profile Control for CMP**
  - ***Hardware & Installation***
  - ***Software & Controller Development***
  - ***Recipe & Process Development***
    - *Thick Cu polish (Platen 1)*
    - *Baseline Damascene (Platen 2)*
    - *Non-flat Incoming Profile*
- **Summary & Conclusions**

Growing 200mm Demand

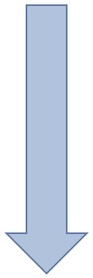
- **Explosion in 200mm demand**
  - *Not every device needs bleeding edge technology*
  - *Growing demand for Analog, MEMS & RF chips*
  - *Shortage in both fab capacity and equipment*



Source: SEMI Engineering, 7-17-2018

Introduction & Motivation

- **Limited Options for 200mm manufacturers:**
  - ***Pay the premium on new/used equipment and charge more for 200mm wafers;***
  - ***Buy used equipment on auction sites and hope it can be repaired;***
  - ***Buy entire fabs as advanced chipmakers sell them off;***
  - ***Add new technology into existing equipment to improve the capacity and capabilities of that equipment (incremental improvements).***

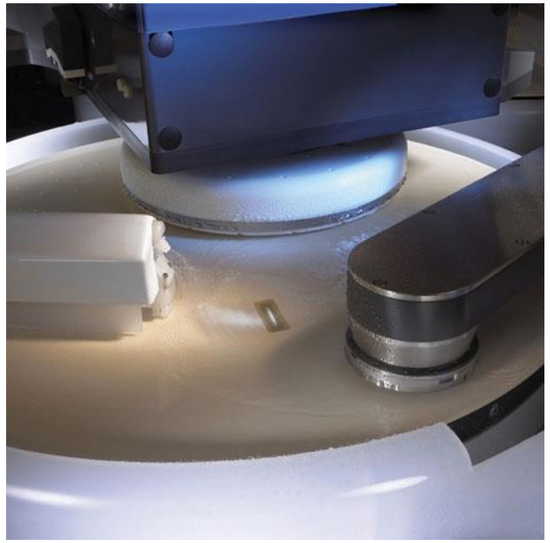


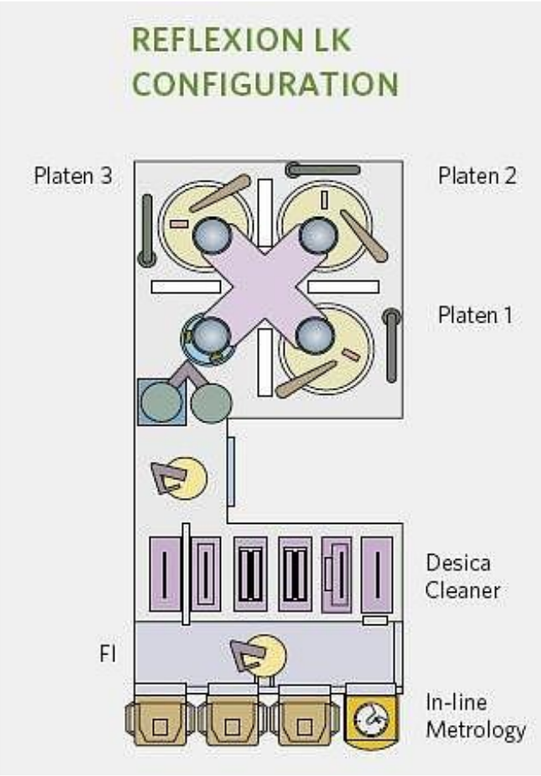
Applied Materials decided to scale production-proven RTPC™ *in-situ* profile control from the 300mm CMP tool set and implement on 200mm tools

Enable new (thick) Cu CMP processes
Handle multiple wafer types & incoming Cu profiles

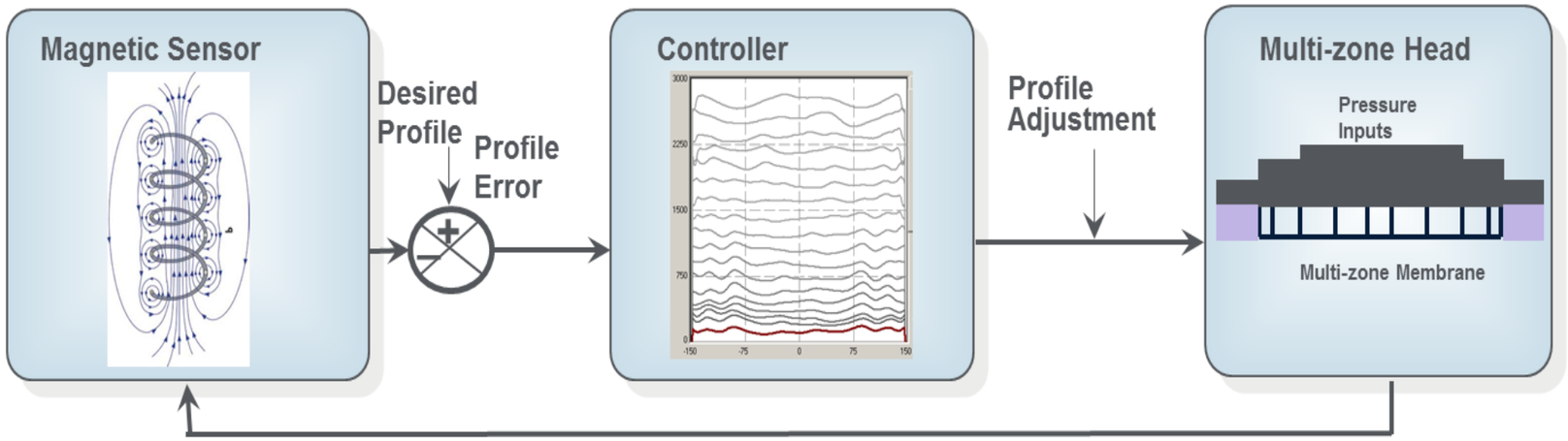
Real-time Profile Control (RTPC) for 300mm CMP

Source: www.amat.com

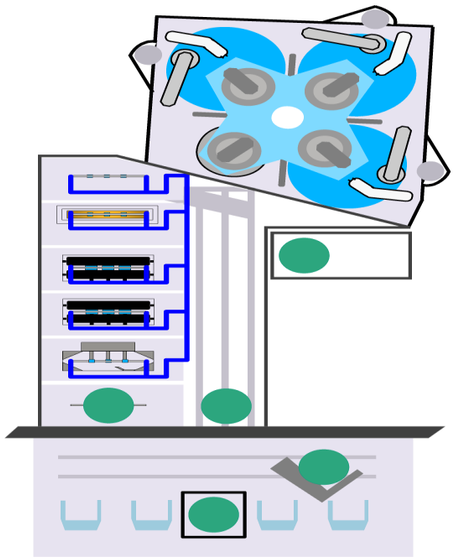




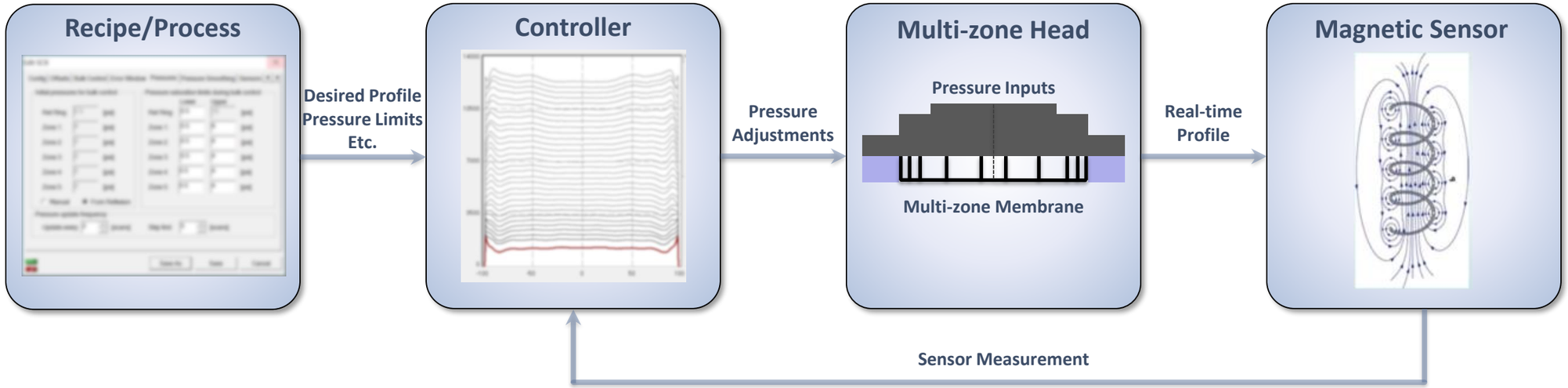
Source: Fabtech, 29 Nov. 2007



Real-time Profile Control (RTPC) for 200mm CMP



Mirra Mesa™



3. Recipe/Process Development

2. SW/Controller Development

1. Hardware/ Installation

RTPC Hardware & Installation

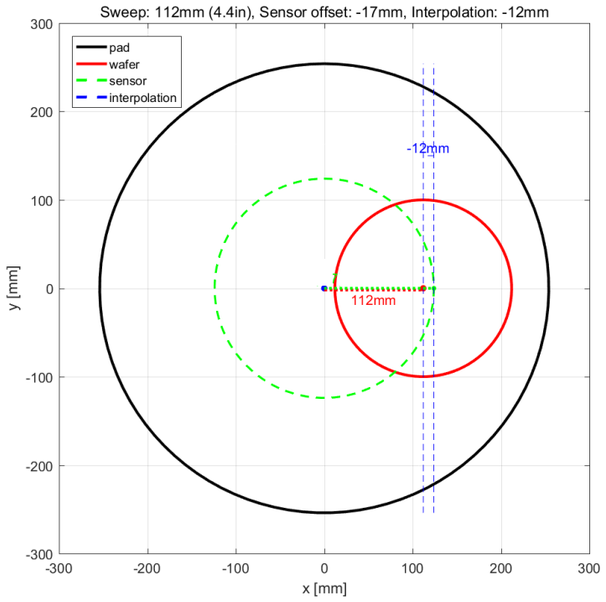
❑ Hardware necessary for RTPC:

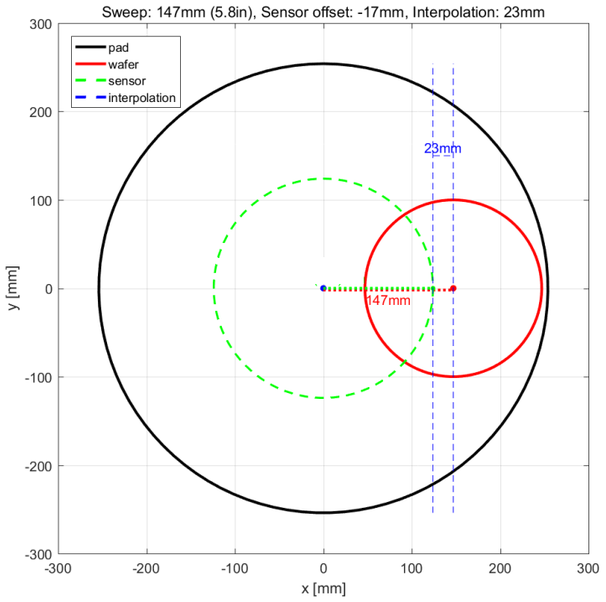
Easy or Difficult Compared to 300mm CMP?

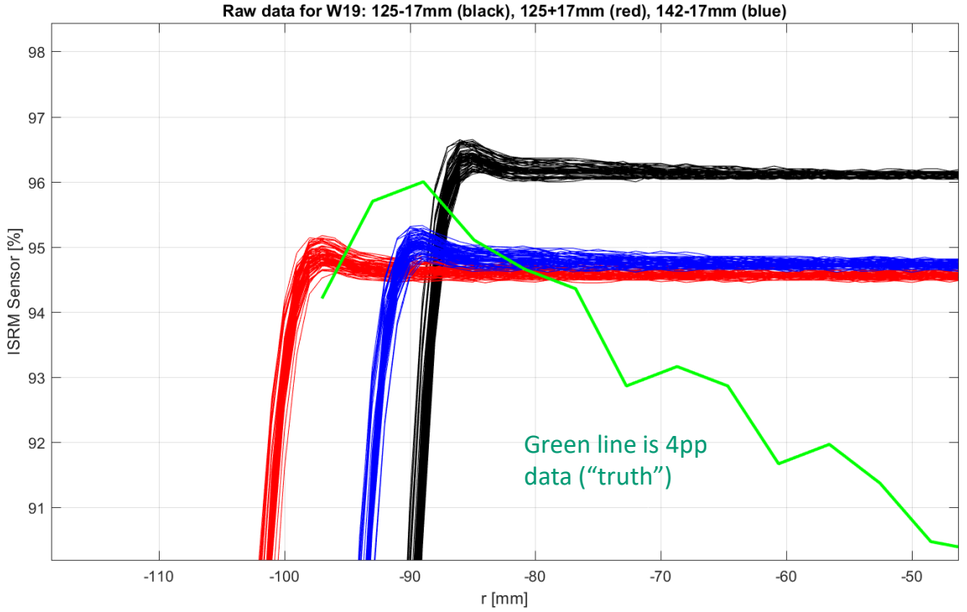
- o *Multi-zone head with multi-zone pressure membrane* → *Already present for 200mm CMP*
- o *Highly sensitive magnetic sensors* → *Already available from 300mm CMP*
- o *Modified polishing pad with integrated sensor window* → *New product, but existing 300mm technology*

❑ Installation of RTPC hardware:

- o *Sensor & pad installation* → *Fairly straightforward*
- o *Sensor placement* → *Common sense geometry*





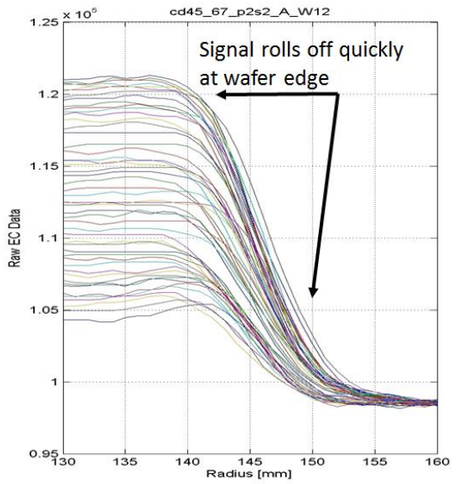


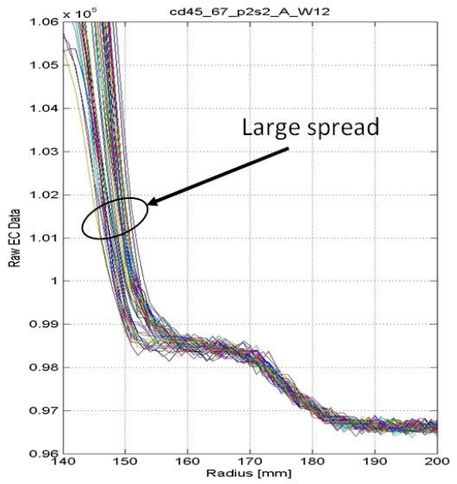
RTPC Software & Controller Development

RTPC Software

Easy or Difficult Compared to 300mm CMP?

- *User Interface* → *Modify 300mm interface to accommodate 200mm*
- *Real-time Signal Processing Software* → *Duplicate/Generalize 300mm SW*
  - *Scaling of Data*
  - *Outlier Detection*
  - *Spatial Filtering (Smoothing)*
  - *Edge Detection and Chatter Correction*
  - *Transformation of Signals to Absolute Thickness*
  - *Calibration for different configurations*





Controller Development

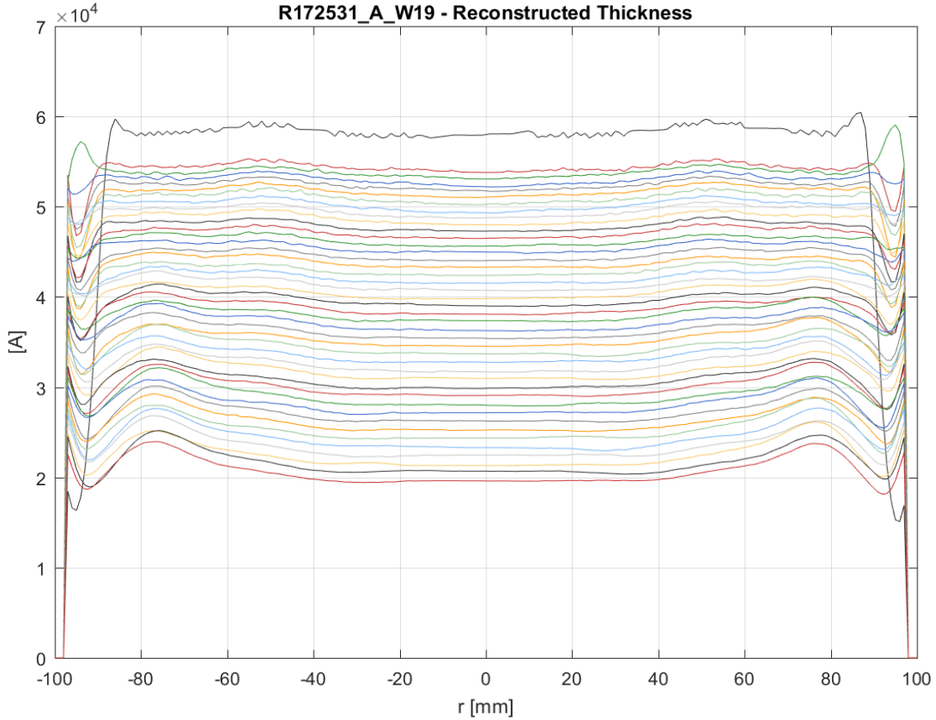
- *Model-based Feedback Control*
  - *Drawing + DOE for Model of Zone Interaction* → *Similar to 300mm CMP*
  - *Feedback Gain design* → *Similar to 300mm CMP*

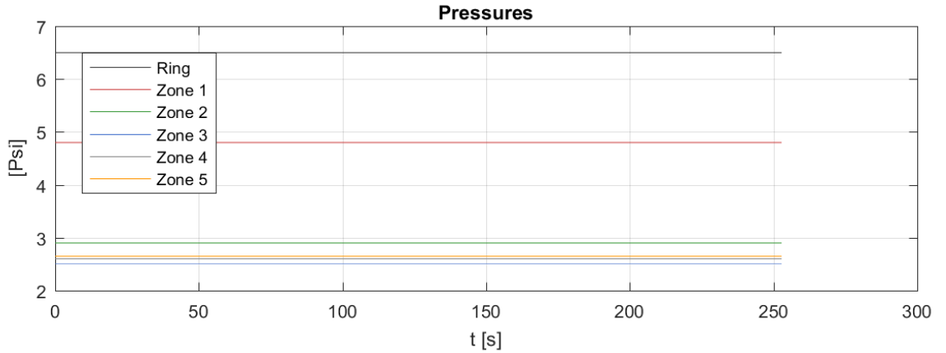
Recipe and Process Development

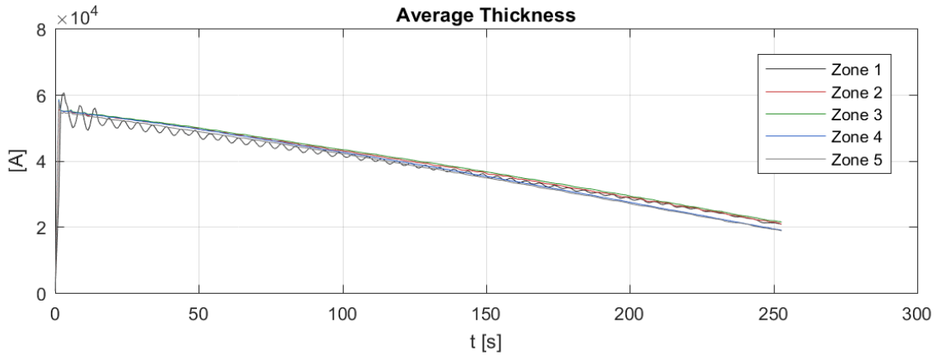
- **Three applications:**
  - ***Thick BEOL Cu (Platen 1)***
  - ***'Standard' Damascene Cu (Platen 2)***
  - ***Non-flat Incoming Profile***

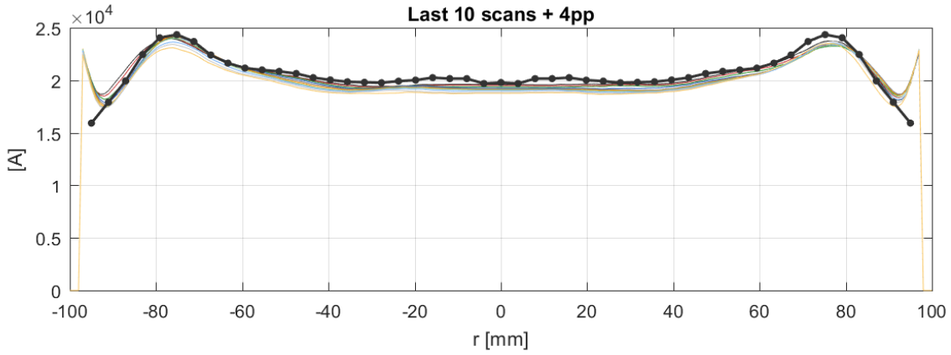
- **Following Results were generated on a modified Applied Mirra® 200mm CMP Tool at an Applied Research partner**
  - ***Open-loop Results***
  - ***Closed-loop Results with RTPC™***

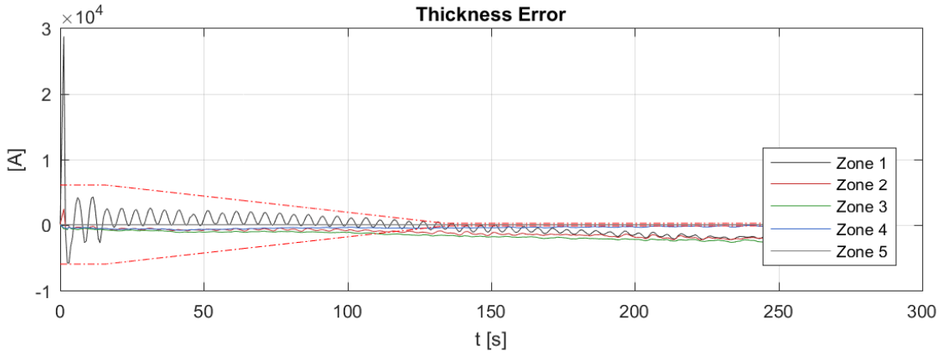
Thick Cu Process (Platen 1): Open-Loop



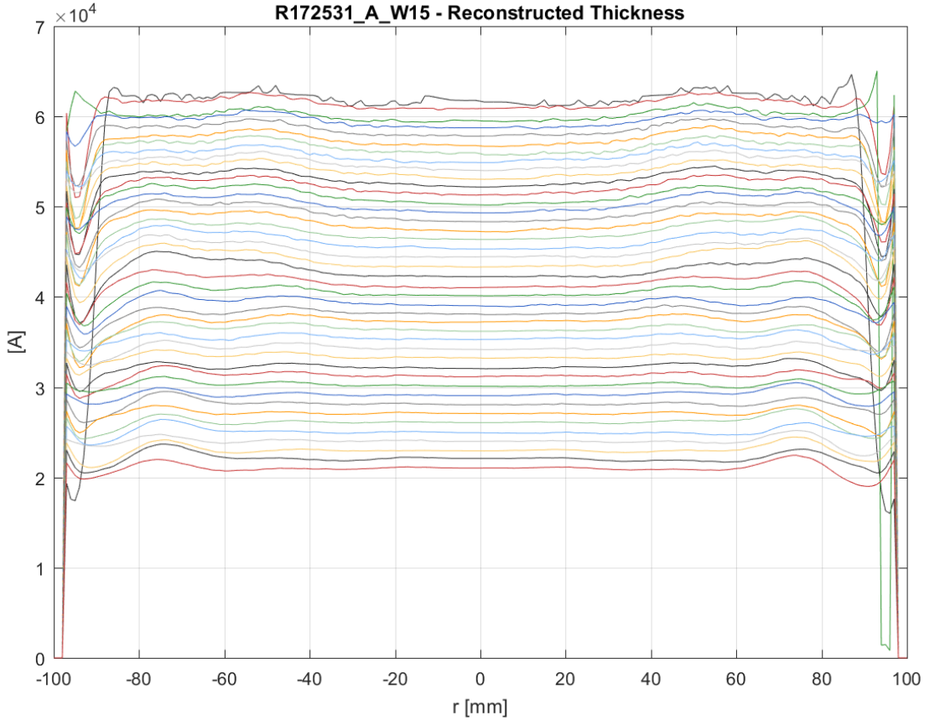


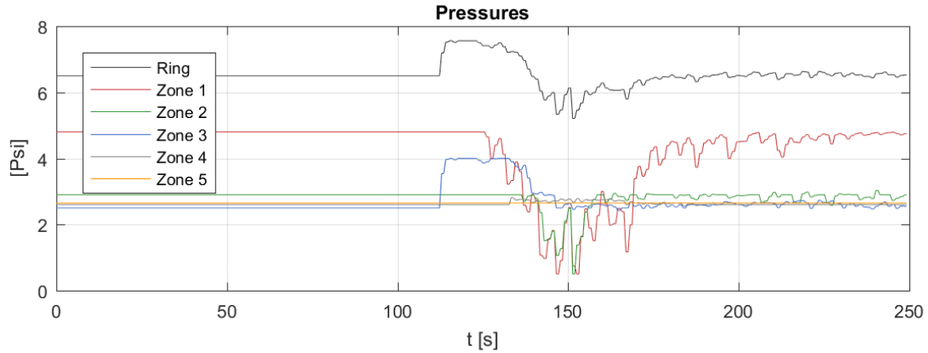


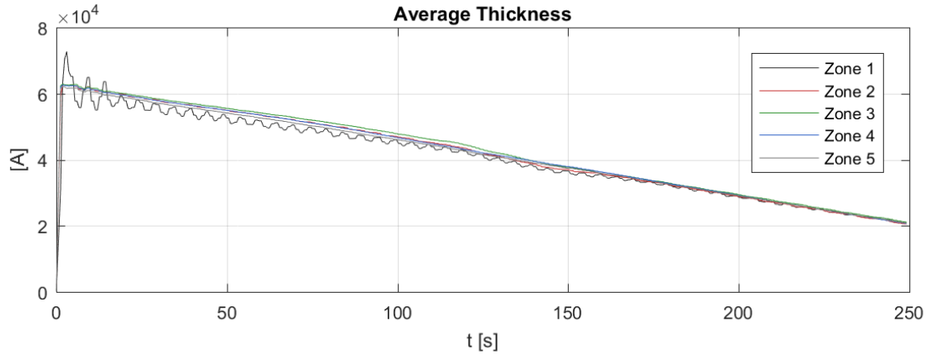


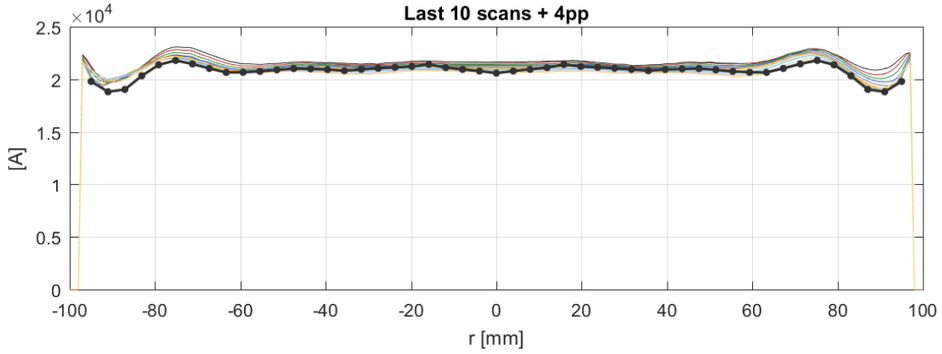


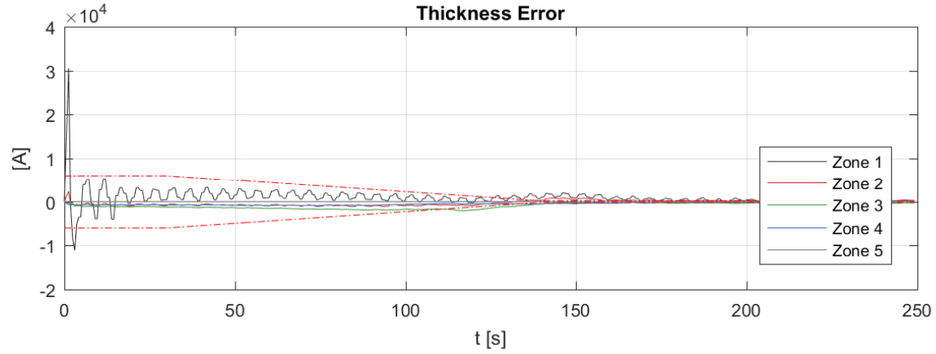
Thick Cu Process (Platen 1): Closed-Loop



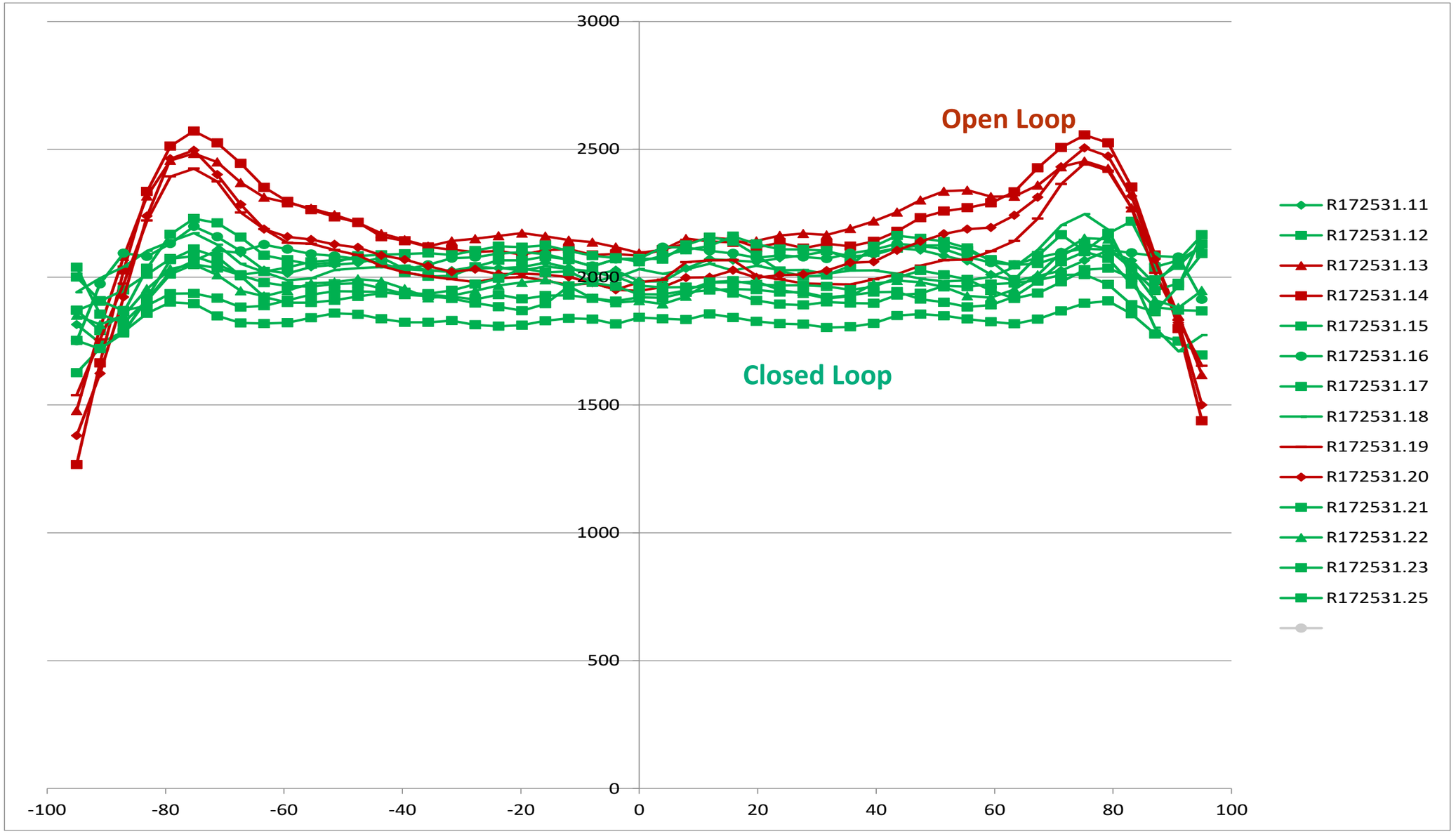




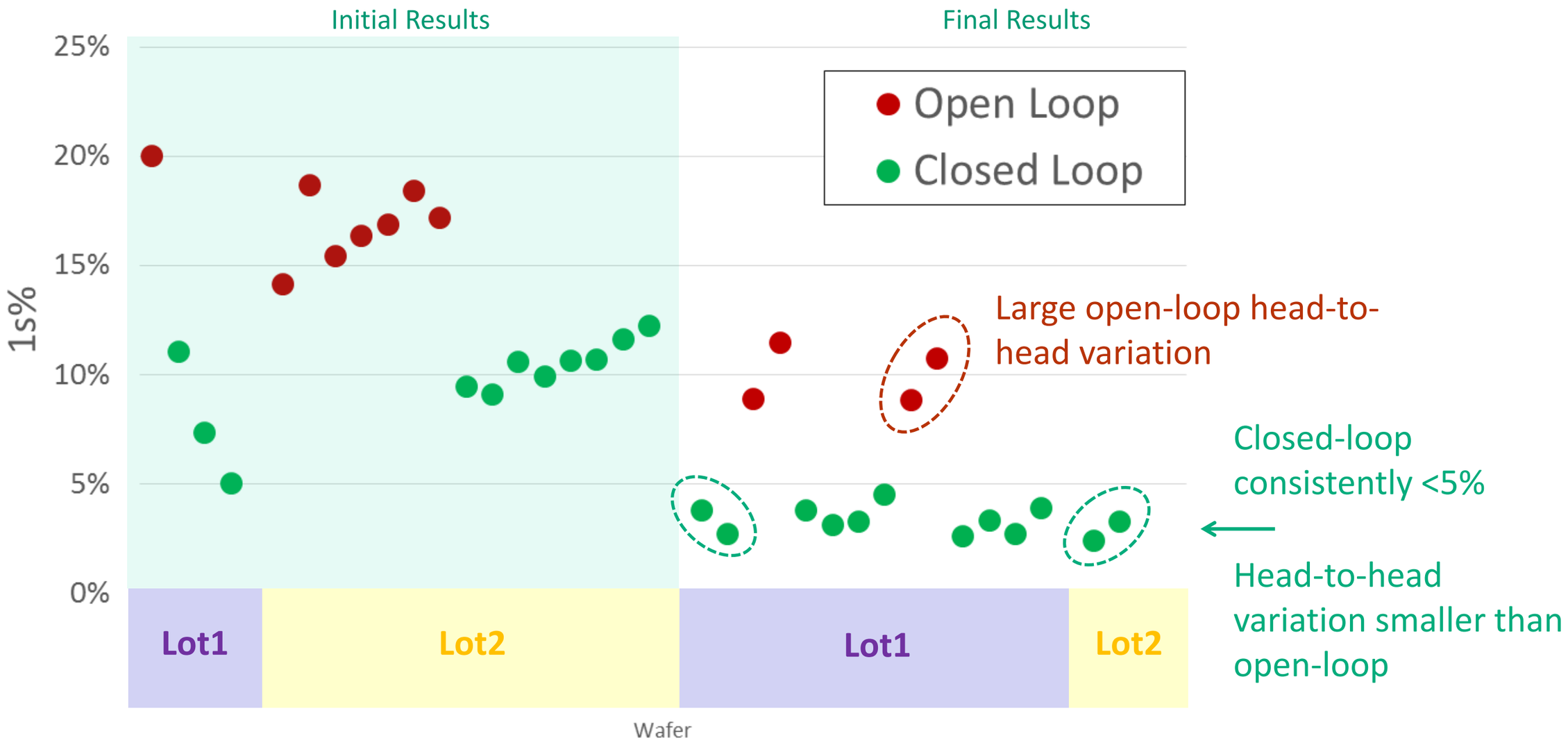




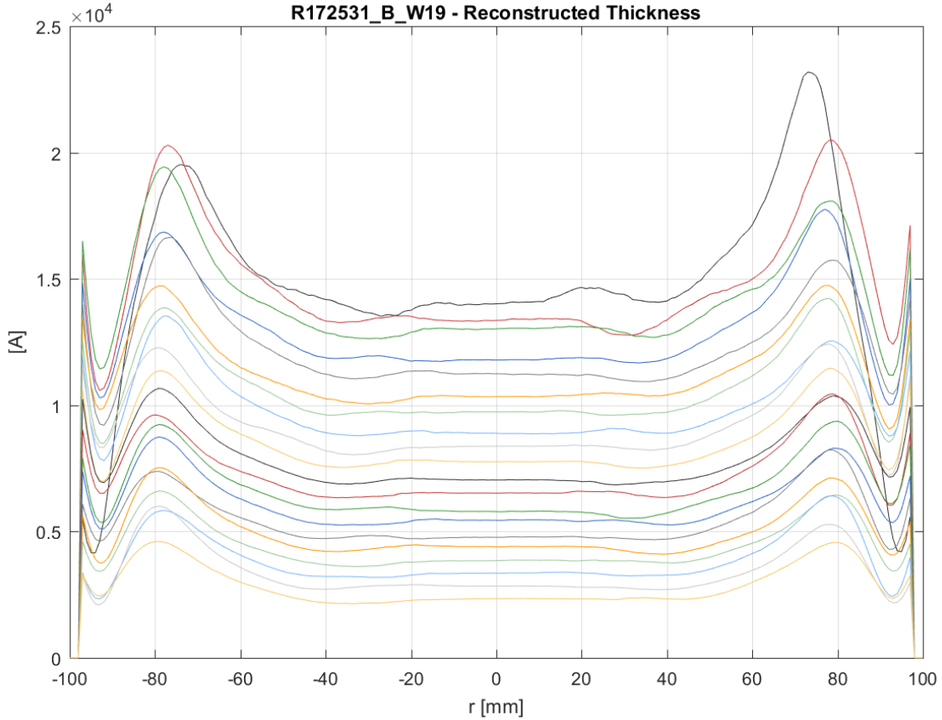
Thick Cu Process (Platen 1): OL/CL Split

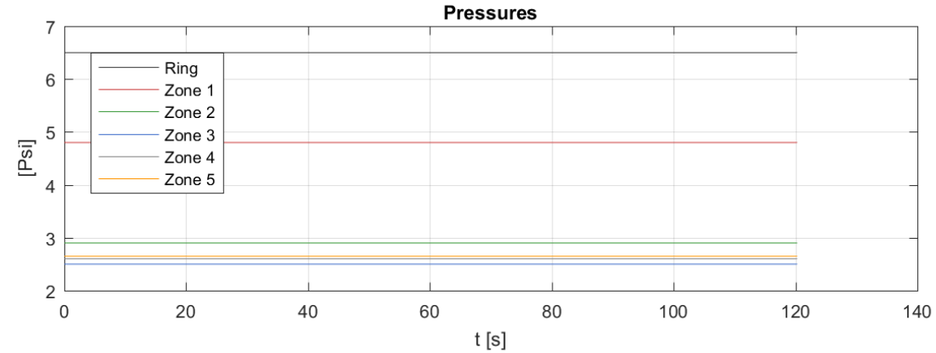


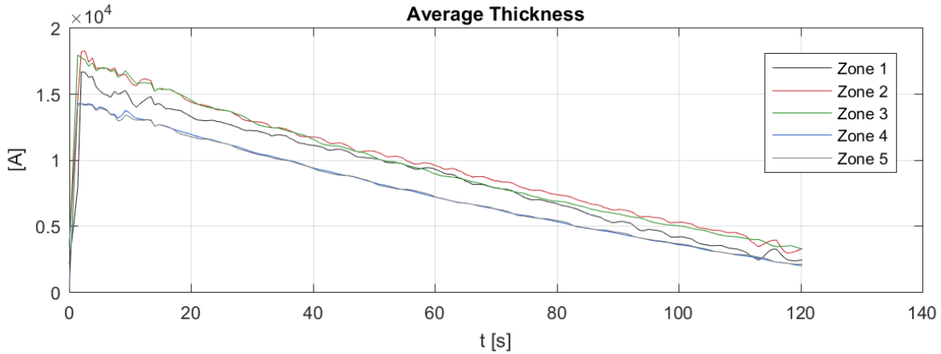
Thick Cu Process (Platen 1): WiW Results

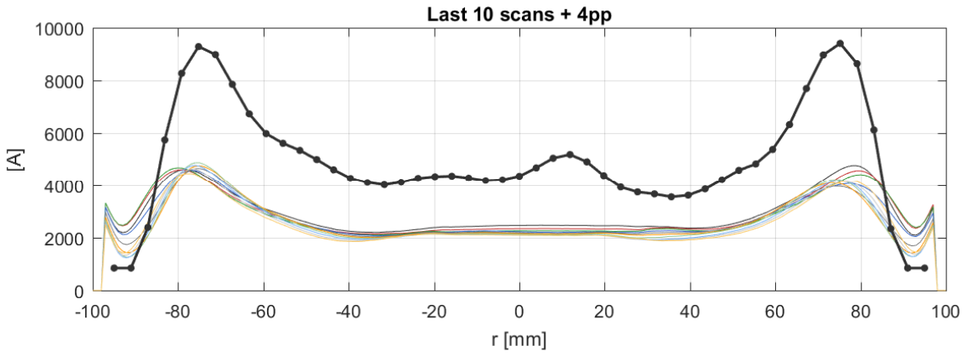


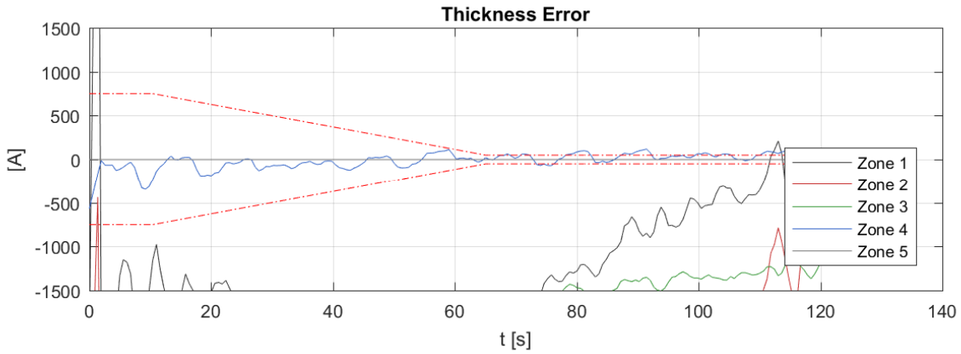
Damascene Cu (Platen 2): Open-Loop





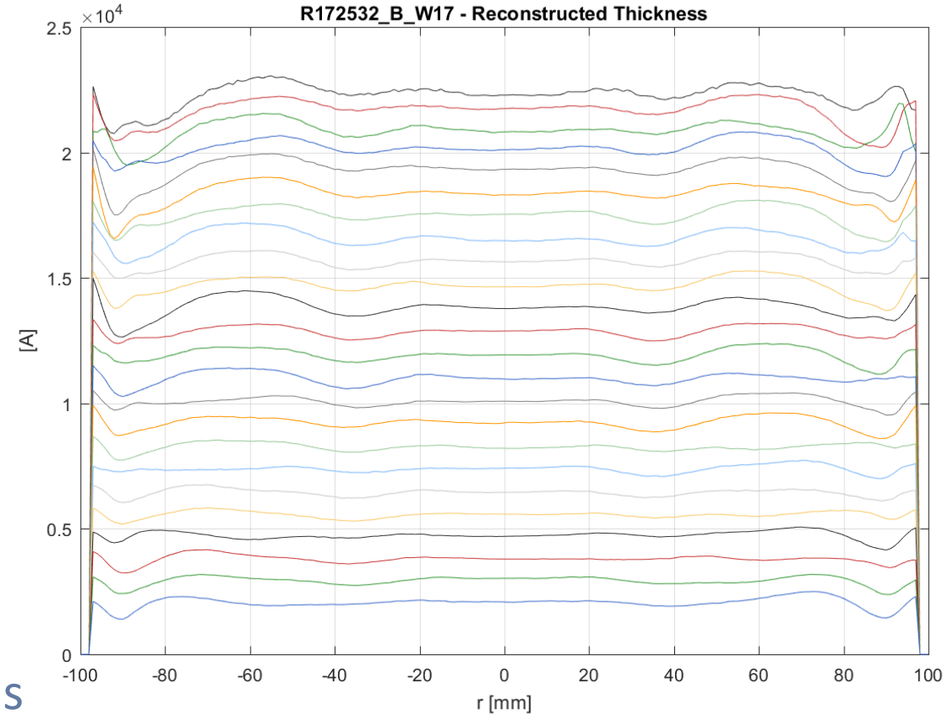


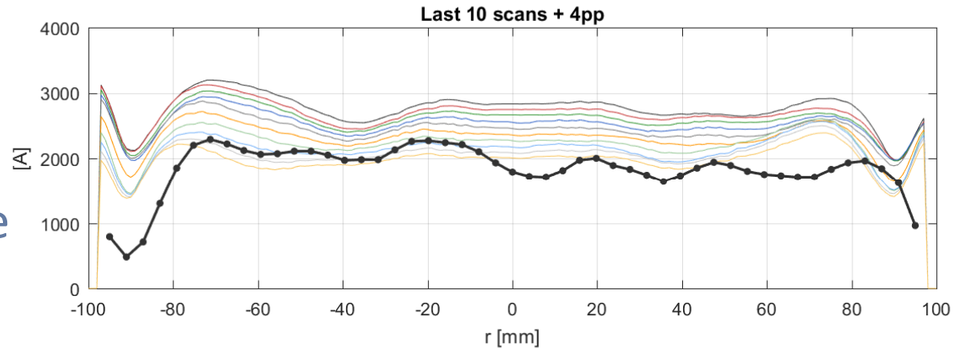


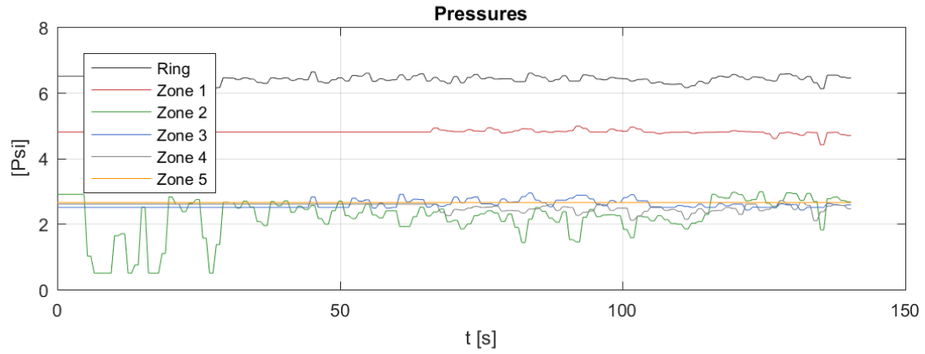


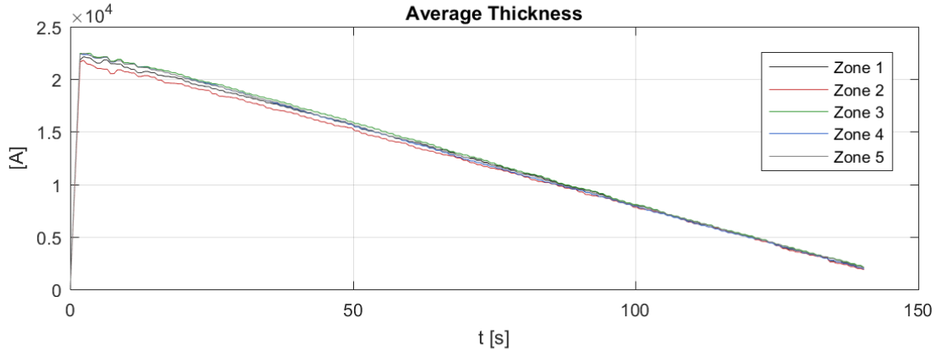
Damascene Cu (Platen 2): Closed-Loop

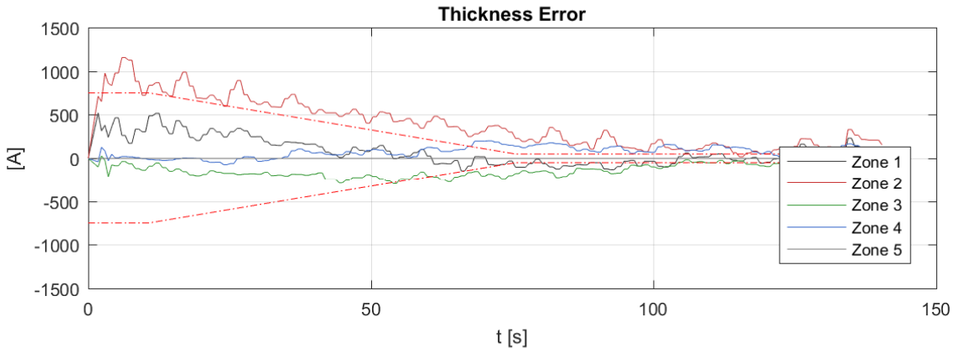
Edge prediction is somewhat off, wafer starts to clear at the edge





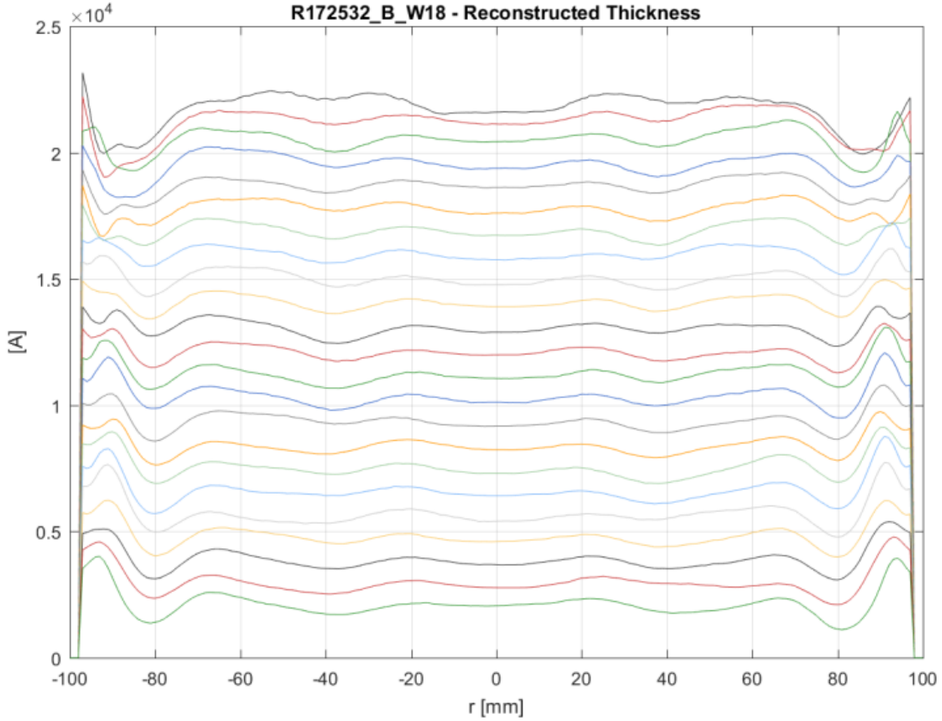


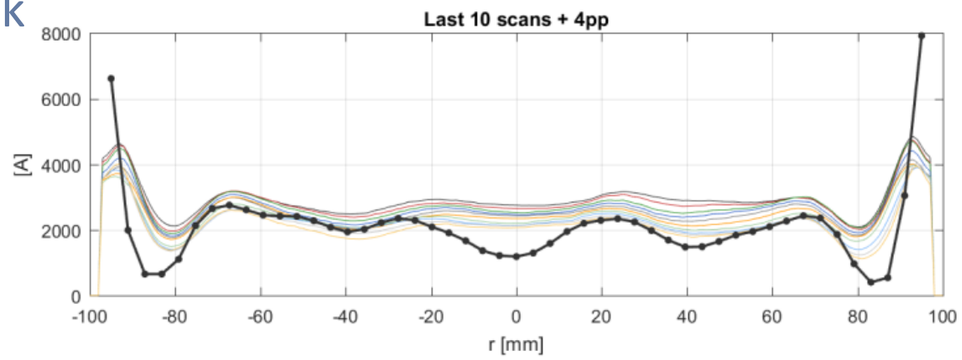


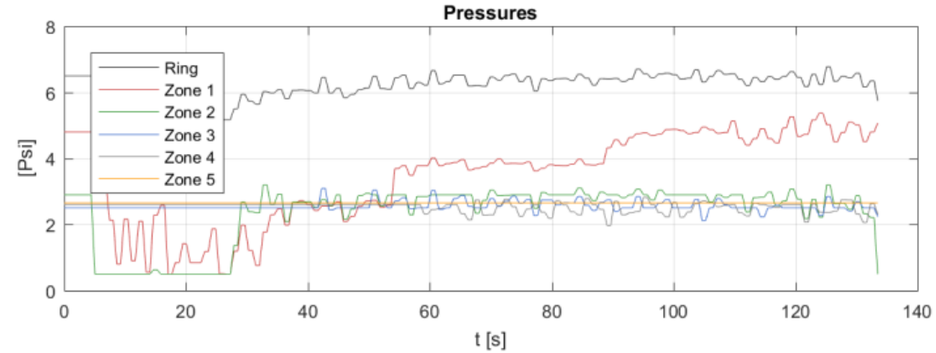


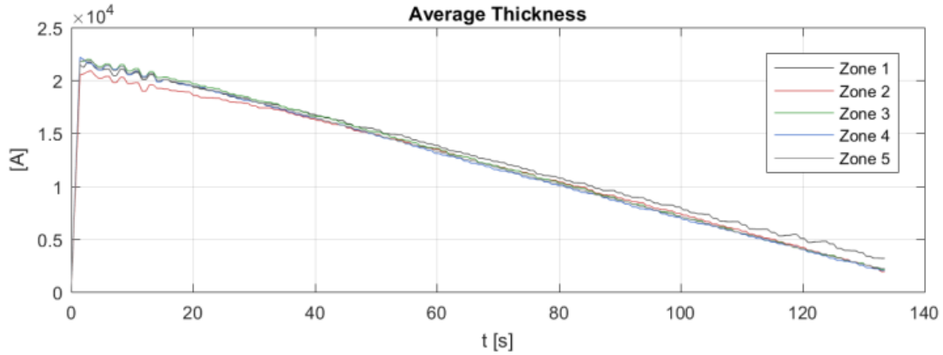
Damascene Cu (Platen 2): Closed Loop (+ offsets)

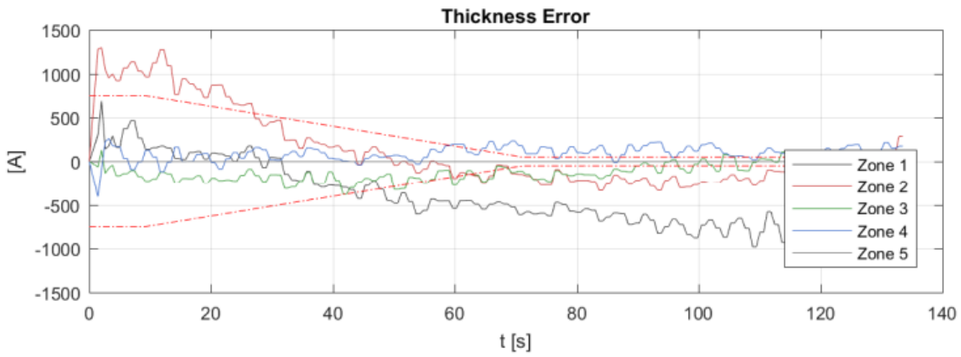
Offsets create thick edge, but ‘dip’ in Z2 starts to clear now



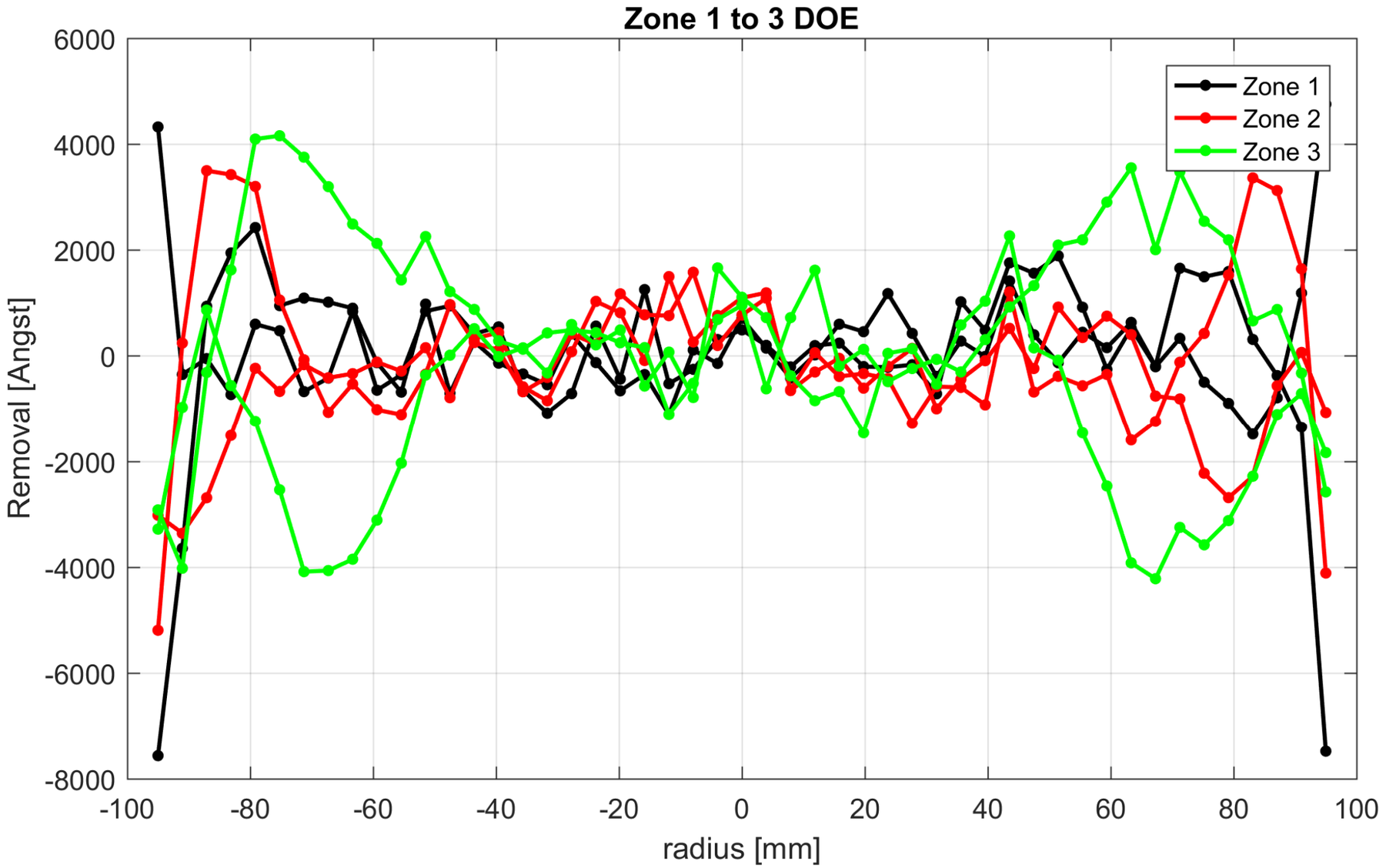




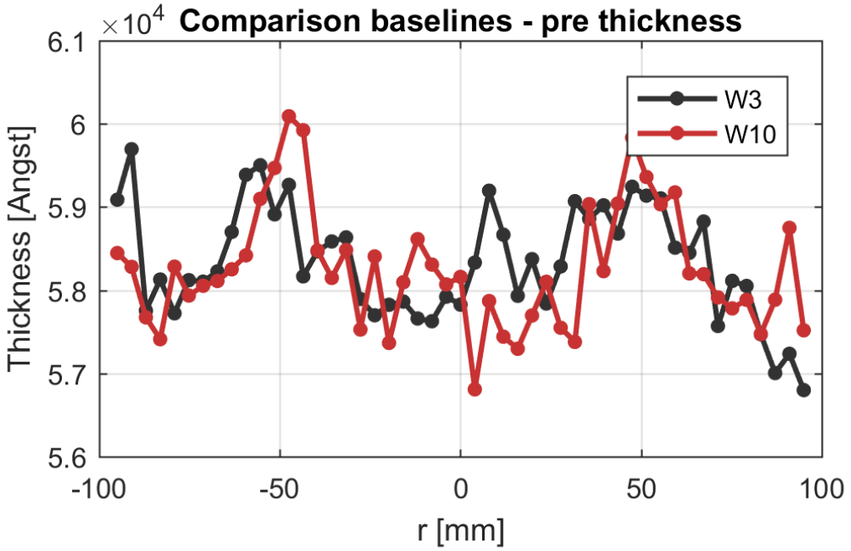


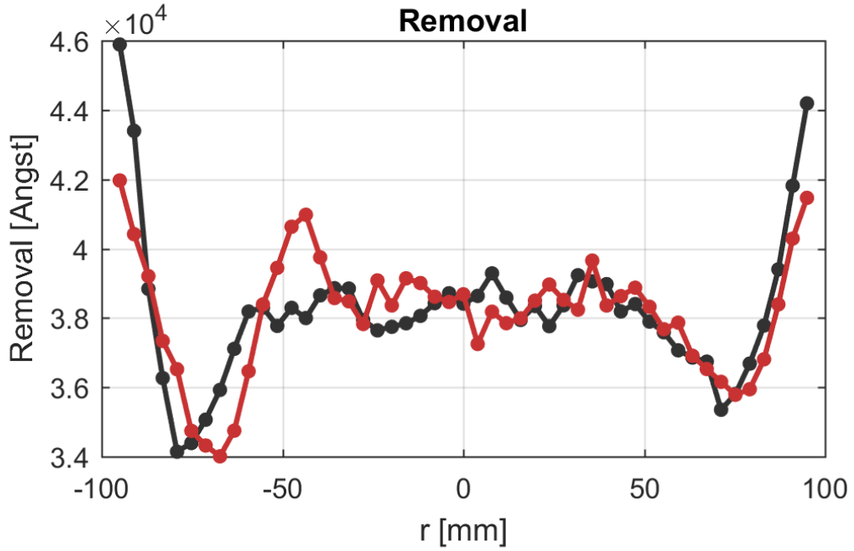


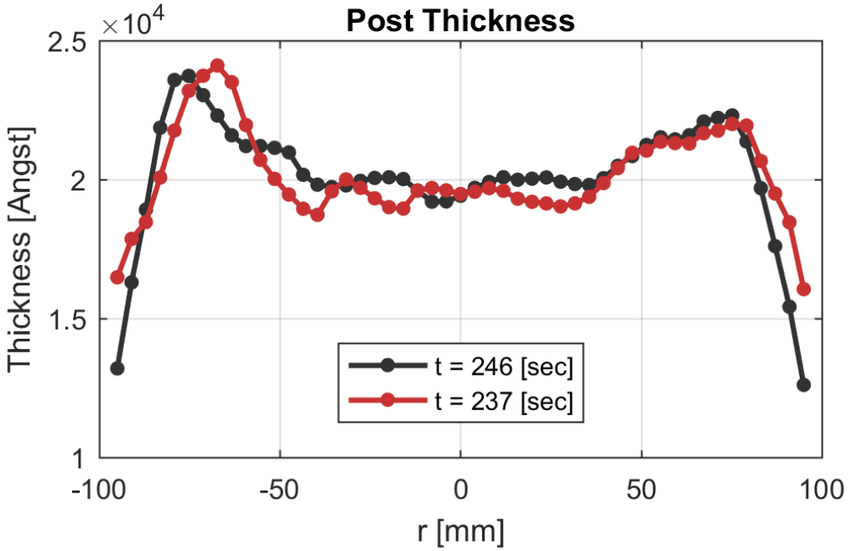
Thick Cu (Platen 1): DOE Edge Removal

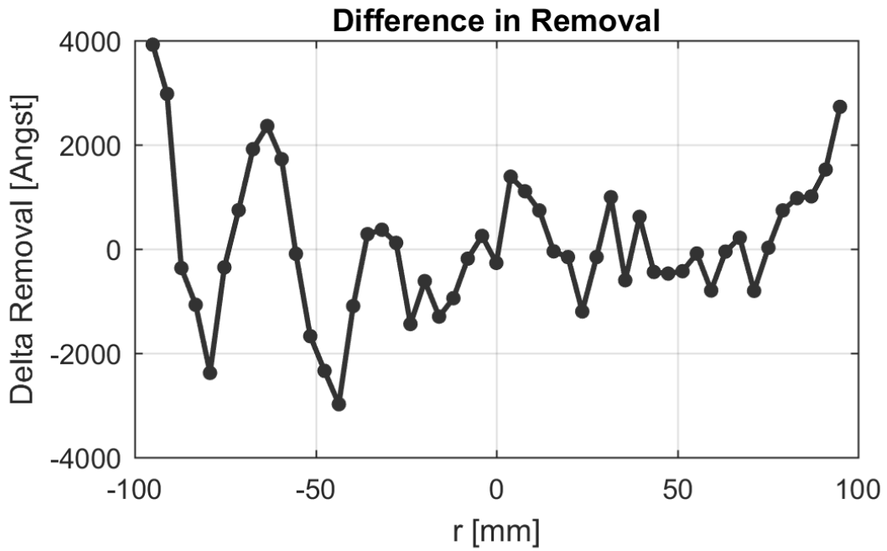


DOE Baseline Data



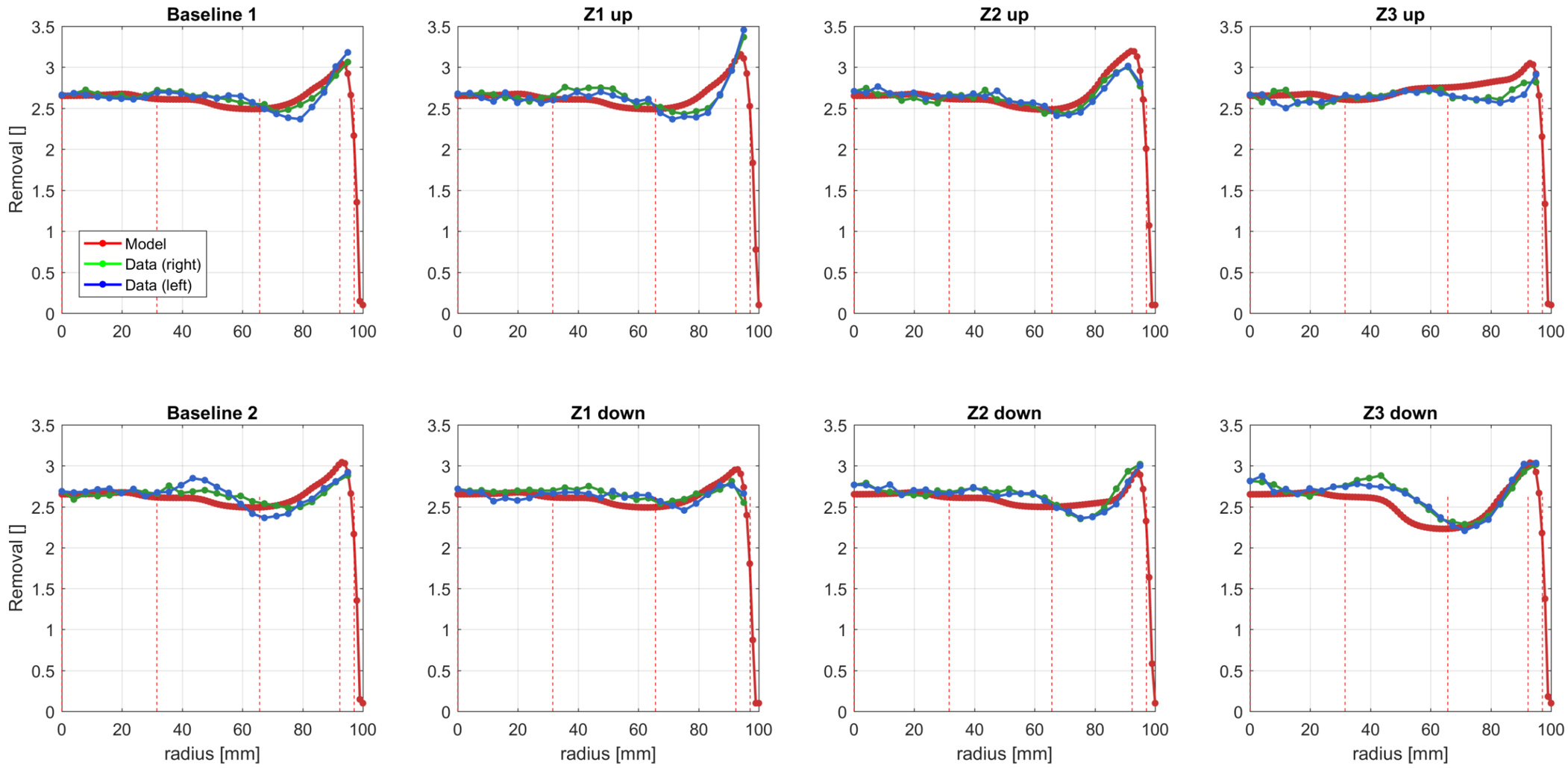




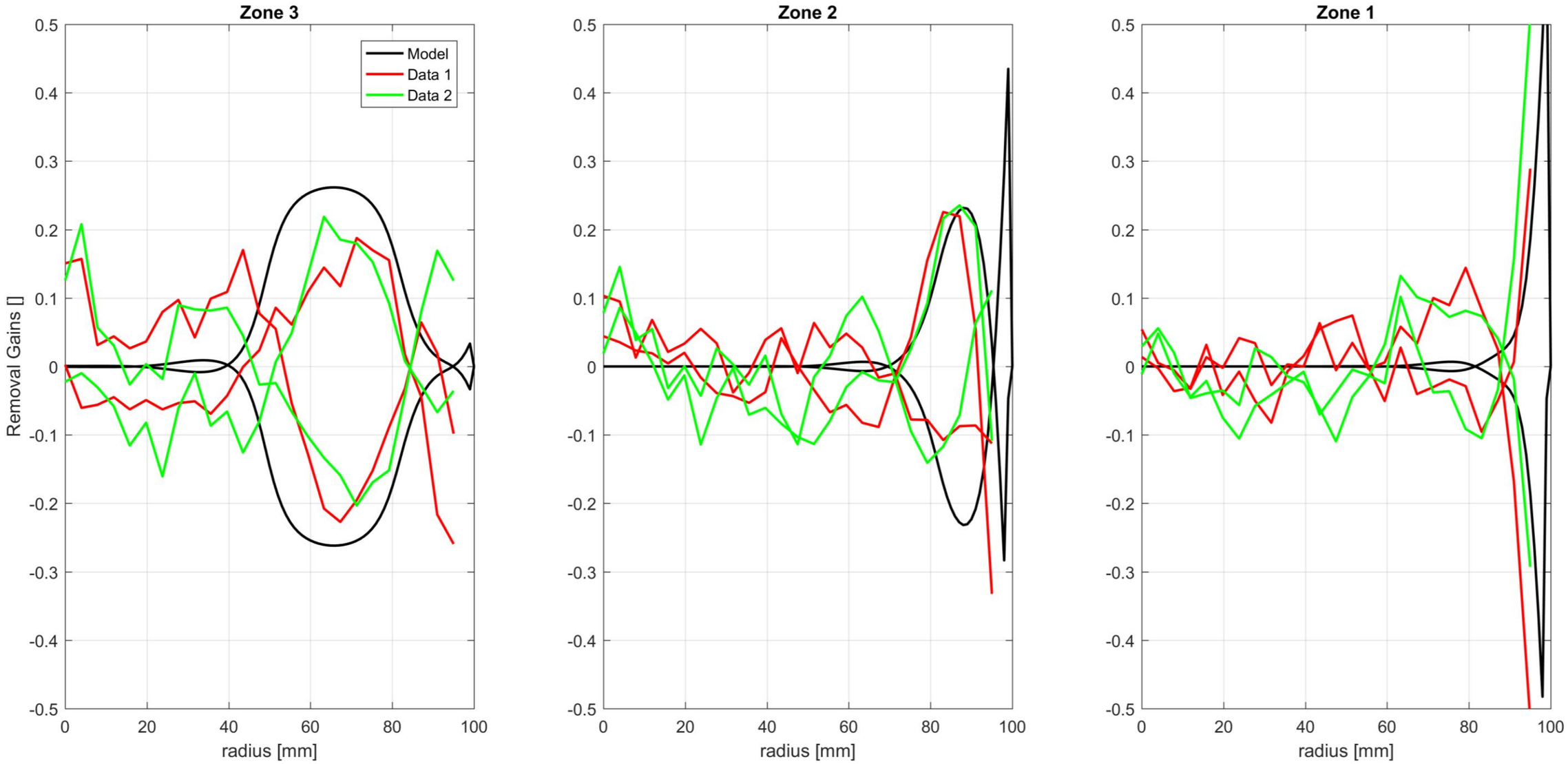


The difference between two 'identical' baselines has a range of 7000A!

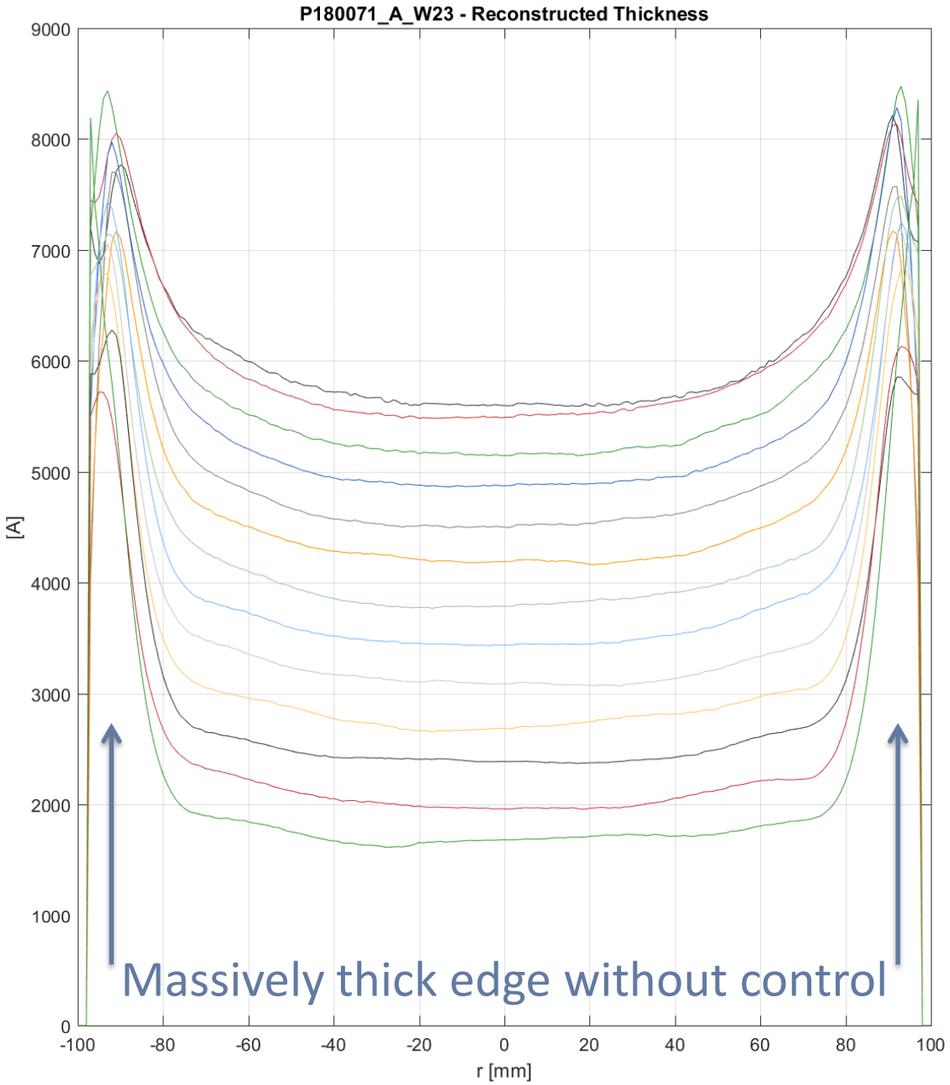
DOE: Model vs. Data

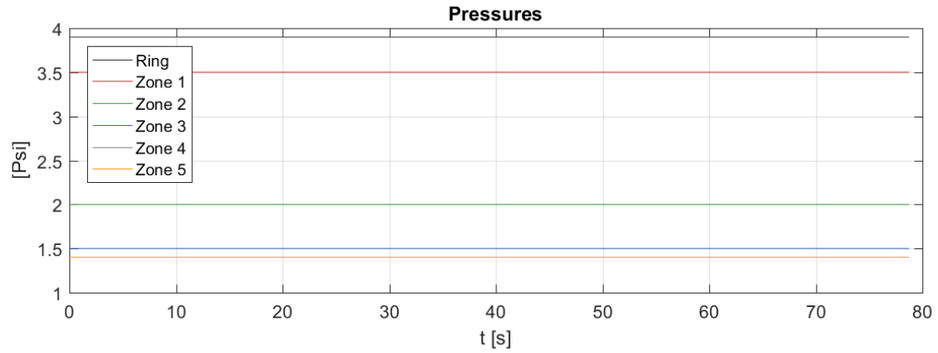


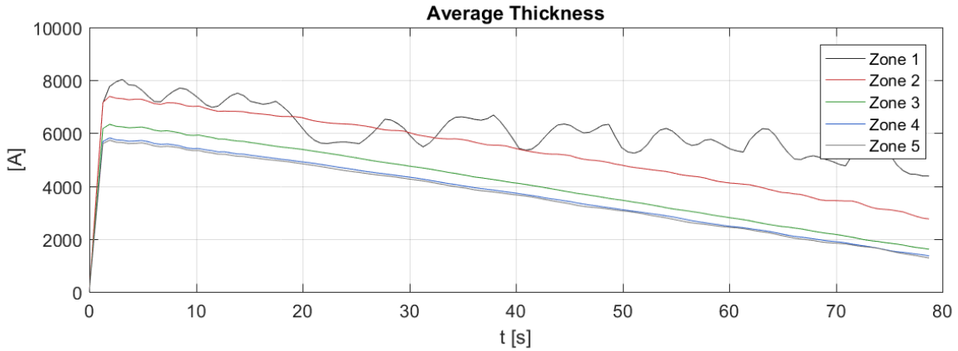
DOE: Model vs. Data

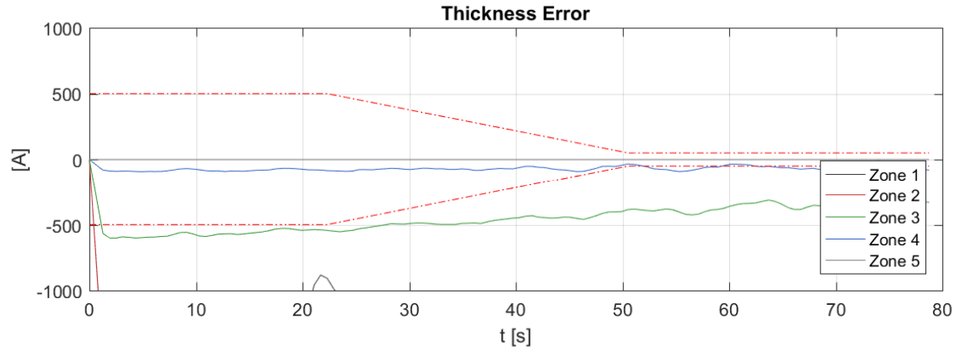


Non-flat Incoming Profile: Open-Loop

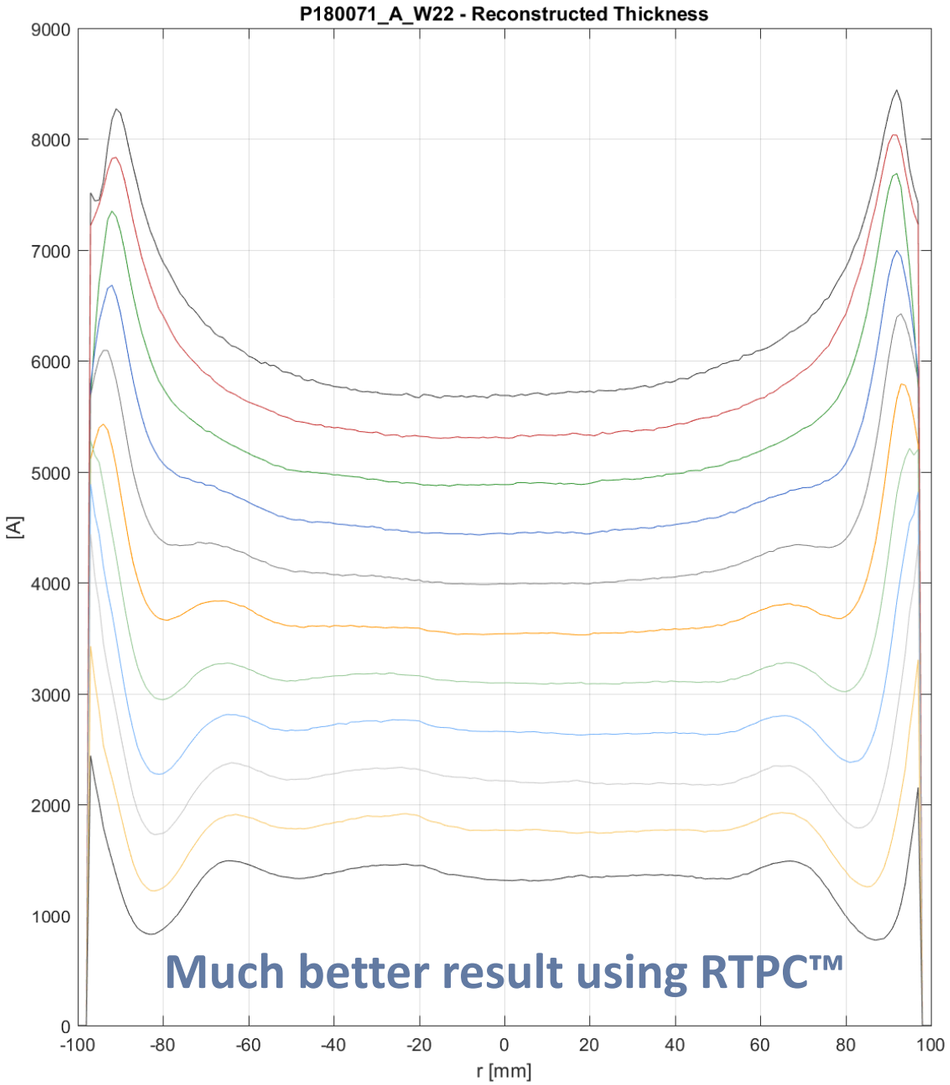


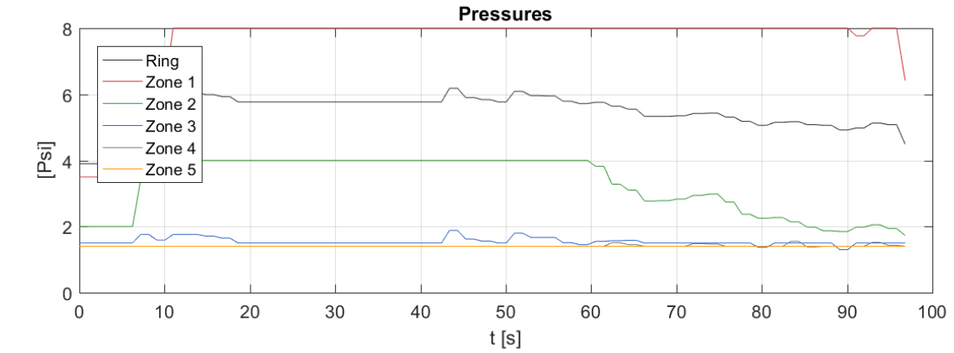


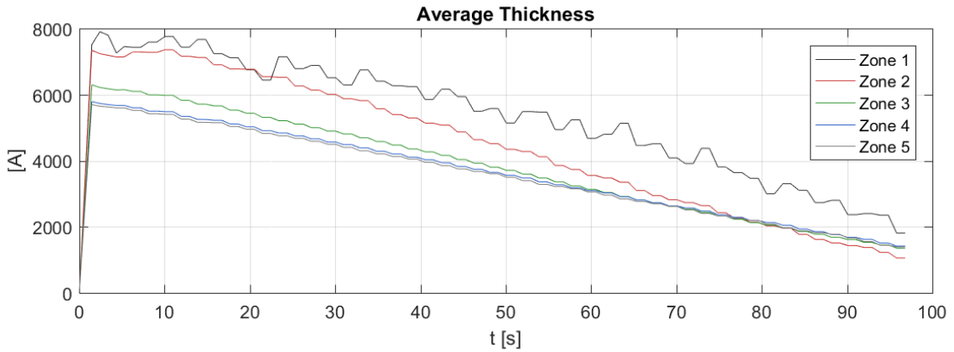


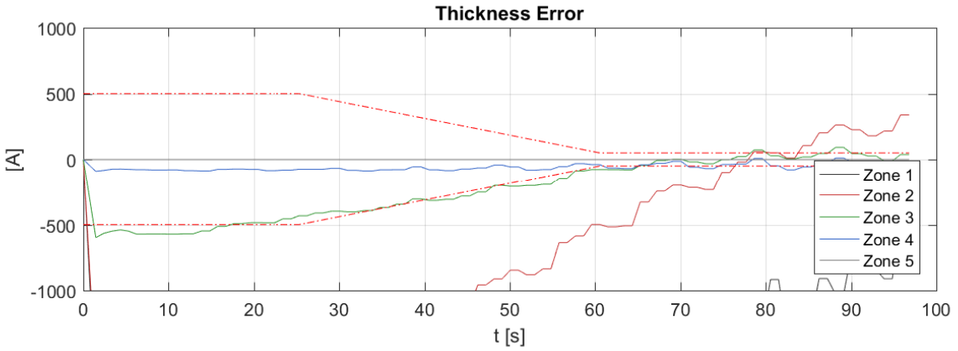


Non-flat Incoming Profile: Closed-Loop









Summary & Conclusions

- **Results were presented of Real-time Profile Control (RTPC™) for 200mm CMP**
  - ***Scaled from Production-Proven 300mm profile control***
  - ***Utilizes existing 200mm Contour Head and highly sensitive "eddy current" sensors in platen***
  - ***Feedback loop uses Model-based Control to adjust polishing pressures***
  - ***Allows control and compensation for all incoming variables like film thickness variations, consumable variation, and head variation***
- **Is Model-Based Profile Control for 200mm CMP easier than 300mm CMP?**
  - ***Development/Installation of Hardware: Yes***
  - ***Development of Software: Yes***
  - ***Achieving Process Results:***
    - *New Process (Thick Cu):* ***No, new challenges arise***
    - *Existing Damascene Process:* ***No, smaller zones pose bigger challenge***
    - *Non-flat Incoming Profile:* ***Similar success as 300mm***
- **Overall, RTPC™ for 200mm CMP is a success with potential significant Return on Investment made for 300mm CMP**

SC SOLUTIONS

Value Through Innovation