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

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Overview

❑ Introduction & Motivation

❑ Real-time Profile Control for CMP
  o Hardware & Installation
  o Software & Controller Development
  o Recipe & Process Development
    ▪ Thick Cu polish (Platen 1)
    ▪ Baseline Damascene (Platen 2)
    ▪ Non-flat Incoming Profile

❑ Summary & Conclusions
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

1. Hardware/Installation
2. SW/Controller Development
3. Recipe/Process Development

Mirra Mesa™
RTPC Hardware & Installation

- **Hardware necessary for RTPC:**
  - Multi-zone head with multi-zone pressure membrane
  - Highly sensitive magnetic sensors
  - Modified polishing pad with integrated sensor window

- **Installation of RTPC hardware:**
  - Sensor & pad installation
  - Sensor placement

- **Easy or Difficult Compared to 300mm CMP:**
  - Already present for 200mm CMP
  - Already available from 300mm CMP
  - New product, but existing 300mm technology

- **Installing RTPC hardware compared to 300mm CMP:**
  - Fairly straightforward
  - Common sense geometry

- **Green line is 4pp data ("truth")**
RTPC Software & Controller Development

RTPC Software

- **User Interface**
- **Real-time Signal Processing Software**
  - 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
  - Feedback Gain design

Easy or Difficult Compared to 300mm CMP?

- Modify 300mm interface to accommodate 200mm
- Duplicate/Generalize 300mm SW

- Similar to 300mm CMP
- 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

R172531_A_W15 - Reconstructed Thickness

Pressures

Average Thickness

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

Open Loop

Closed Loop
Thick Cu Process (Platen 1): WiW Results

Initial Results vs. Final Results

- **Closed-loop** consistently <5%
- **Open Loop**
- **Closed Loop**

Large open-loop head-to-head variation

Closed-loop consistently <5%

Head-to-head variation smaller than open-loop

Lot1 | Lot2 | Lot1 | Lot2

Wafer
Damascene Cu (Platen 2): Open-Loop
Damascene Cu (Platen 2): Closed-Loop

Edge prediction is somewhat off, wafer starts to clear at the edge.
Offsets create thick edge, but ‘dip’ in Z2 starts to clear now
Thick Cu (Platen 1): DOE Edge Removal
The difference between two ‘identical’ baselines has a range of 7000Å!
DOE: Model vs. Data

Baseline 1

Z1 up

Z2 up

Z3 up

Baseline 2

Z1 down

Z2 down

Z3 down

Removal [

radius [mm]
DOE: Model vs. Data

Zone 3

Zone 2

Zone 1

Removal Gains

radius [mm]

radius [mm]

radius [mm]
Non-flat Incoming Profile: Open-Loop

Massively thick edge without control
Much better result using RTPC™
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