Particle challenges in spin/spray cleaning tools

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Outline

- Cleaning challenges of EUV masks
  - Issues with current single-mask cleaning tools
  - Development of new cleaning module based on Levitronix Spin System
- Sources of particles in the cleaning tools
  - UPW
  - Chemicals
- New progress in sub 10 nm particle metrology in UPW
Cleaning challenges of EUV masks

Electrostatic chucks damage backside of the EUV masks and create particles that need to be removed.
Front and backside cleaning in the current mask cleaning tools

- Most cleaning processes only clean the front side of the plate
- During front side cleaning backside will be sprayed with DI water
- For backside cleaning, the plate will be flipped and backside will be cleaned
- During backside cleaning front side will be sprayed with DI water
- Backside flow is scattered by chuck holding posts
- Any chuck contamination can be transferred to the down face of the plate
Challenges of the backside cleaning

Front Side

Before cleaning

After cleaning

Backside

Before cleaning

After cleaning

Only front side cleaning
No backside cleaning

SPM (Front) → SPM (back) → SPM (Front) cleaning
Strategy for backside cleaning

- **Tool component development**
  - Issue with all existing spin-spray tools
  - New chuck is required

- **Process development**
  - Managing/controlling surface energy of Ru during cleaning process
  - Process development on Ru capped ML are in progress
  - Few of experimental processes seem promising

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![Diagram of tool component development](image1.png)

![Graph showing contact angle vs. time](image2.png)
New technology for simultaneous cleaning of the front and back surface.

Traditional systems with single surface cleaning:
- Chuck post splash
- shaftless motors

New systems with simultaneous both surface cleaning:
- shaftless motors
- chuck post splash

[Diagrams showing the new technology for simultaneous cleaning of the front and back surface.]
Levitronix Spin System

- Levitronix Spin System is a magnetically levitated shaft-less motor with large 300 mm opening
- Levitronix Spin System is ideal for simultaneous cleaning of both surfaces
Development of a double-sided mask cleaning system based on Levitonix Spin System

- SEMATECH and Levitonix engaged in a JDA to develop a new system for cleaning advanced masks based on Levitonix Spin System

Development included:
  - Design and built of a standalone module (SAM)
    - Mask chuck
    - Chuck and motor optimization
    - Liquid handling and nozzles
    - Cleaning arms
    - Automation
    - Software
    - Safety features
  - Integration in a wet clean tool
    - Hardware integration
  - Chamber optimization
    - Air flow optimization
    - Fluid handling optimization
  - Process optimization
    - Cleaning process development
Application of Levitronix Spin System for mask cleaning

Motor ➔ Mask Chuck ➔ Concept design

Integration in the wet clean tool ➔ Standalone module (SAM)
SAM in operation

- SAM is fully functional with integrated software based on Labview
- Wet functionality and safety tests have been completed
- Optimization of airflow in chamber is in progress
Process development - Rinse/ Dry adders

Very first test
Rinse/dry

Optimized
Rinse/dry

Dry test-FFU Low

FFU High

• Rinse/dry process was optimized by air flow optimization
Flow generated in gap by chuck rotation

HIGH ROTATION RATES-NO INLET OR OUTLET FLOW

- Higher chuck rotations result in higher flows in gap
Air flow modification by air rings

- Addition of air gaps can improve flow uniformity near the gap
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Current status
Particle generation by air flow in chambers

- Air flow dynamic in the chamber is playing a major role in article contamination
- Many process parameters impact fluid dynamic in the chamber
  - Plate position, angular velocity, ramping, exhaust, FFU’s flows, chamber geometry
Particle adders in cleaning tools

- Particles are added by
  - Chemicals, tool, process, UPW, airborne
Particles in chemicals and UPW

- Many particles are added by chemicals and UPW
- There are more particles in hot UPW than in cold UPW
Particle counts in UPW with 25 nm LPC sensitivity

- Particles were measured in a wetbench with filter configuration shown.
- An average of 6 particles per liter with size of >25 nm.
- Capture efficiency of the counter in 25 nm is unknown.
Valves and tubing are adding very small particles.
- Valves were kept in open position without any dynamic movement

There are major challenges in tackling sub 30nm defectivity.
4X improvement is needed for detection of small particles in the chemicals.

Detection of low concentration of particles is needed to test, valves, pumps, and filter retention.
Non Detectable Particles

- Cleaning processes add very small particles (10 nm to 17 nm) SEVD that **CANNOT** be detected with existing defect inspection tools.
Strategy for detection of sub 25 nm particles in UPW

• Further technology development is required to see sub 25 nm particle
  – Develop techniques to increase the concentration of particles in UPW (e.g. evaporation of water)
  – Use CPC based systems to measure small particles
  – Identify nonvolatile dissolved solid in UPW
  – Develop methods to put sub 10 nm particles on the surface
  – Develop methods to characterize sub 10 nm particles
CPC based LPC is able to detect particles and non volatile residues in UPW by using a new nebulizer (TSI Inc).

Development work is in progress to adapt this technology for **low concentration** of particles in **chemicals**.
Controlled particle deposition

- Controlled deposition of nanoparticles in a desired location is needed to develop fundamental understanding of particle adhesion and removal in sub 10 nm regime.

- Nano particle characterization techniques (TEM) should be developed for such small particles.

5 nm Au
On Si Surface

![AFM image of 5 nm Au on Si surface](image)

![STEM image of 5 nm Au on Si surface](image)
Characterization of 5nm particles

- SEMATECH successfully deposited a known 5 nm particle (Au) on a desired location on the surface and characterized by TEM (using High Angle Annular Dark Field detector and EDS)

5nm Au on SiN membrane

Credits: D. Balachandran, J. Harris-Jones, M. Samayoa, E. Stinzianni
Summary and conclusions

- The Levitronix Spin System was developed into a mask cleaning system in SEMATECH
  - A successful JDA between SEMATECH-Levitronix
  - Initial functionality tests have been completed and further development work is in progress

- Process chemicals and UPW are one of the main sources of particle defectivity in the cleaning tools

- SEMATECH has enabled sub 10 nm defectivity research
  - 5 nm particles were deposited on the desired location
  - Compositional and topography analysis were done for 5 nm particles
  - Study of sub 10 nm natural defects are in progress
Acknowledgment

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Other sources of particles in tools

Dry process

- Endeffector
- Cold DI -back
- Hot DI -back
- Gas manifold
- Operator fingerprint

- Many sources contributed to particle generation in clean tools/processes