ESH-Friendly Cleaning and Rinsing of Multi-Material Surfaces and Structures

(*Task Number: : 425.043)*

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Challenges in Cleaning and Rinsing of Multi-Material Surfaces and Structures

- Fabrication of current state of the art devices requires cleaning and rinsing of sub-micron size structures

- The complexities in rinsing of these structures arise from:

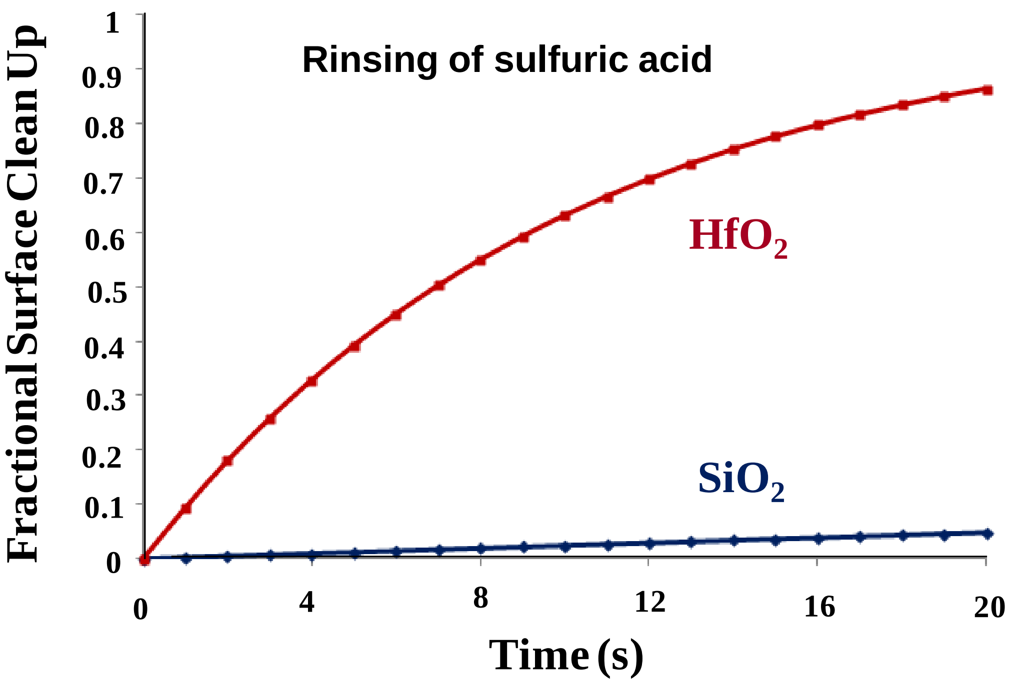
    - Differences in wettability of various surfaces
    - Inhibited rinsing in regions with lower wettability and contributions to watermark and post rinse residues
    - Slow transport of cleaning chemicals and rinsing water in and out of the structures
    - Impurity retention due to surface interactions and surface charge effects

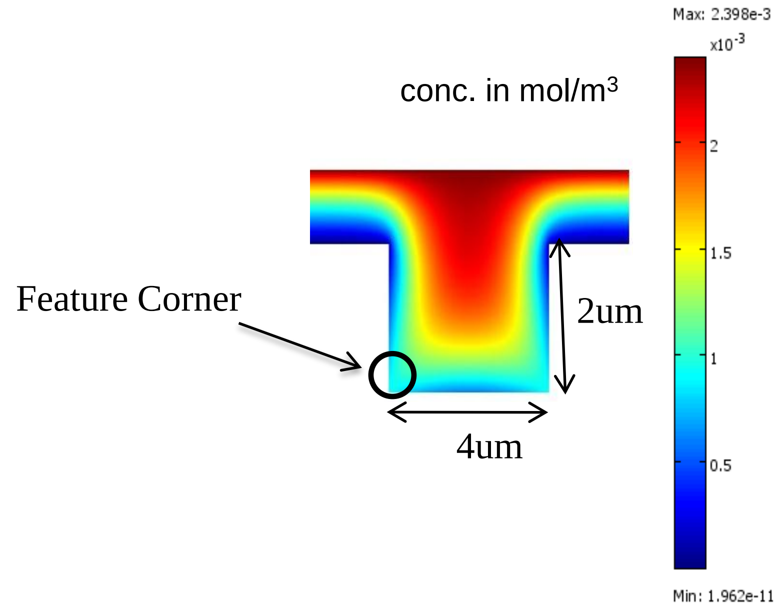
- The conventional rinsing processes have not been designed based on the rinse process bottlenecks and lack in-situ and real-time monitoring

Effect of Surface Characteristics on Rinsing Effectiveness

Example showing rinse efficiency of HfO_2 and SiO_2 Surfaces

(Results from previous ERC project)





Wafer Size: 450 mm ,

Flow Rate: 2 lit/min,

Wafer Rotation: 800 rpm

Different dielectric materials have significantly different impurity retention, rinsing dynamics, and cleaning efficiency

Objective and Method of Approach

Objective:

- **Understand the bottleneck of the rinse process involving small structures that consist of different materials**
- **Develop innovative methods to enhance the rinsing process**

Method of Approach:

- ***Subtask 1*: In-Situ and Real-Time Investigation of Rinsing of Multi-Material Structures**
- ***Subtask 2*: Megasonic Enhancement of the Rinsing Process**
- ***Subtask 3*: Process Simulation and Optimized Low-Water Rinse Recipe Development**

ESH Impact

Robust and efficient rinse processes would have a major ESH impact by reducing the usage of water and energy

Proposed Work

Subtask 1: *In-Situ and Real-Time Investigation of Rinsing of Multi-Material Patterned Wafers*

Test structures equipped with real-time and in-situ monitoring sensors will be designed, fabricated, and used.

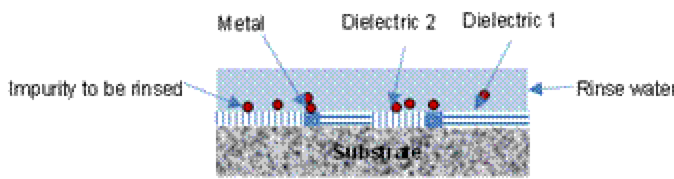


Figure 1a. Example of a planarized heterogeneous surface consisting of materials of different surface properties

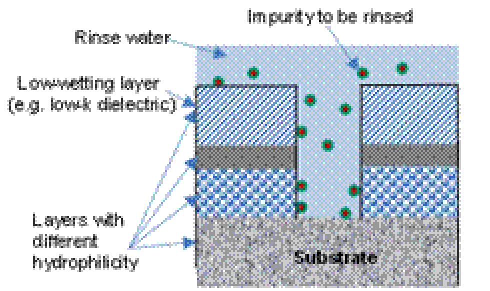


Figure 1b. Example of low wetting material at the mouth of a structure to be cleaned

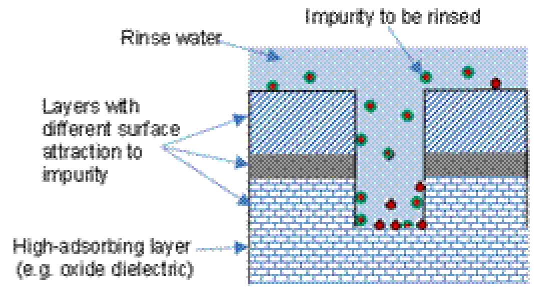
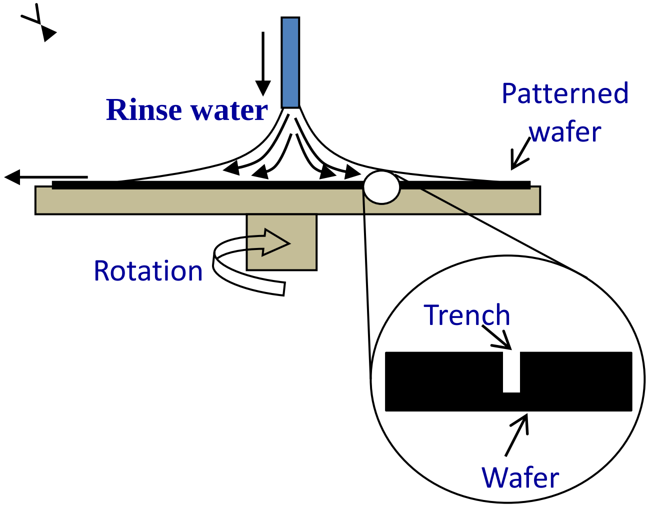


Figure 1c. Example of deep layers with high attraction to impurity to be rinsed

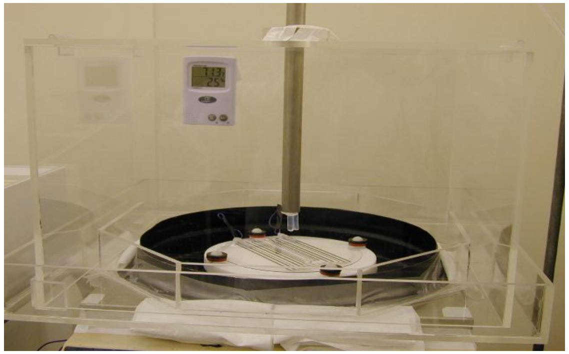
Proposed Work

Subtask 1: *In-Situ and Real-Time Investigation of Rinsing of Multi-Material Patterned Wafers*



Unique experimental single-wafer spin tool equipped with real-time impedance spectroscopy probe will be used to investigate:

- **The dynamics of rinse process**
- **The bottleneck of the process in terms of location and type of surface/material**
- **The role of key operational parameters**
- **The significance of wettability and fluid penetration in nano-structures**



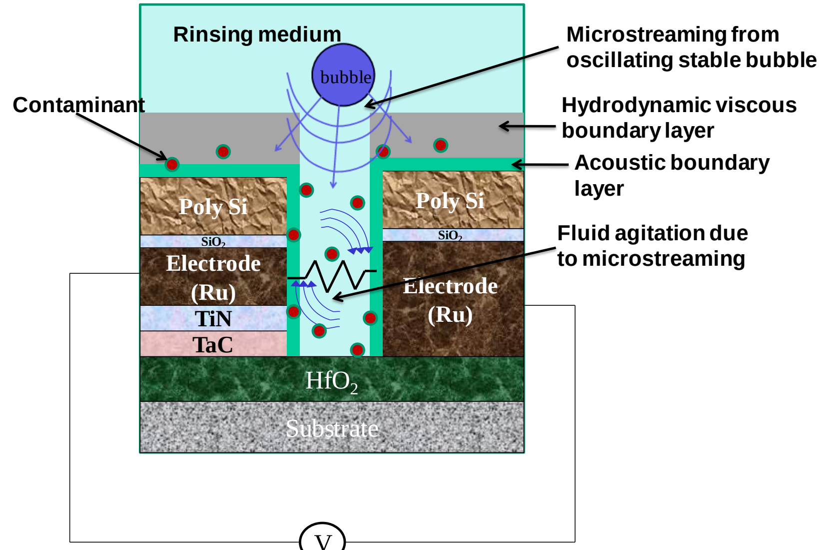
Proposed Work

Subtask 2: *Megasonic enhancement of the rinsing process*

❖ **Application of megasonic field can cause significant microstreaming and improved mass transport of contaminants**

❖ **The use of megasonic energy in improving the mass transport of contaminants out of the narrow trenches and enhancing the overall rinse efficiency will be explored**

❖ **Effect of power density and solution variables (temperature, dissolved gas content) on rinsing efficiency and feature damage will be investigated**



Schematic showing effects from application of a sound field in liquid

Proposed Work

Subtask 3: *Process Simulation and Optimized Low-Water Rinse Recipe Development*

Development of a Rinse Model (incorporating flow due to convection, diffusion, acoustic field and surface effects including adsorption/desorption)

To analyze the rinse data

To facilitate the development of new and efficient rinse process

Model will include

- **Effects of surface charging, surface adsorption and desorption characteristics, and surface wettabilities of different films**
- **Enhancement effects of megasonic application and rinsing process**

Process model will be validated with the direct measurements and used for study of process operation parameters and low-water recipe development

Timeline and Deliverables

❖ **Fabricate heterogeneous multi-material rinse test structures** Q1-2 (2012)

❖ **Conduct rinsing experiments using the test structures to identify key solution and process variables that affect rinsing performance** Q2-4 (2012)

❖ **Develop a rinse model using the experimental data that will determine the bottle neck of the rinse process and allow prediction of rinse efficiency under different process conditions.** Q1-3 (2013)

❖ **Evaluate effect of sound field in improving the rinse efficiency** Q2-4 (2013)

Timeline and Deliverables

❖**Carry out damage studies on test structures and indentify conditions that reduce damage while maintaining rinse efficiency** Q1-2 (2014)

❖ **Modify and refine the model developed earlier to incorporate the enhancement effect of megasonic application on rinse performance** Q2-3 (2014)

❖ **Optimize and develop a single wafer process that is capable of providing significantly improved damage-free rinsing performance** Q3-4 (2014)

Planned Interactions and Cost Sharing

- **Fab level tests to verify rinsing data obtained at U of A will be carried out in collaboration with the *Freescale group* (coordinated by Hsi-An Kwong), and *Samsung Electronics* (Jeongnam Han and Kuntack Lee)**

- **Technical meetings will be held with contacts from *TEL* (Ian Brown), *Micron* (Niraj Rana), *Global Foundries* (Akshey Sehgal) to discuss progress of the project and any deviations needed to be in-line with the industry standards.**

$30k/year committed cost sharing from UA and AZ/ TRIF Program