Pre SiGe Wet Cleans Development for sub 1x nm Technology Node

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Background

- Due to higher aspect ratio features observed in advanced technology nodes (1x nm and smaller), the epi growth uniformity suffers across wafer.
- Carbon, fluorine and oxygen residues incoming from post etch and ashing steps degrade the surface cleanliness and inhibit the epitaxial growth = missing epi defects.
- Need C, O and F at low levels simultaneously going into epi deposition.

Objective

- Improve pre-Epi wet cleans to ensure a pristine surface suitable for uniform epitaxial growth.
- Ensure wet cleans equipment is not contributing to WiW non-uniformity.
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Sub 1x nm HVM Requirements for Pre-EPI Wet Cleans

- POR wet cleans are two-step cleans (back to back)
- HVM Requirements:
  - Eliminate carbon, fluorine and oxygen residues from cavity and SPCR Ox
  - SPCR Ox loss is minimal (= limited dHF usage in wet clean steps)
  - Retain cavity shape and size
  - Zero WiW non-uniformity
Pre-EPI Wet Clean Splits and XPS Results

- **POR two step wet clean baseline**
- **POR with shorter queue time**
- **DIO₃ based HF last wet clean**
- **DIO₃ based clean with upstream etch process changes**

April 2, 2018
Sub 1\text{x} \text{nm} HVM Requirements for Pre-EPI Wet Cleans

- DIO$_3$ based wet clean did not lower missing epi defectivity to required levels

- SIMS pad measurements not reflective of C, O and F removal from SPCR Ox and epi cavity

Therefore, we had to develop a new pre-epi wet clean
Results from 1\textsuperscript{st} Split Lot

- **New pre-epi wet clean**
  - \(R_{on}\) \(\downarrow\) to largest extent with New wet clean
  - Cavity size is unchanged
  - \(~50x\ \downarrow\) in missing epi defects
Post Implementation Results

SPC chart for Missing Epi after implementation as POR

- Missing EPI

- New Pre-Epi Wet Clean
  - Accomplished with no change in SPCR dimension from old POR
  - Pristine wafer surface required additional changes in upstream processes
  - Further optimization in progress
1. Achieving Pristine Wafer Surface with Pre-Epi Wet Clean

2. Improving Cavity Size WiW Uniformity
Need for WiW Uniformity Improvement

- In sub 1x nm wet cleans, the pre-epi wet clean requires complete post etch residue removal and precise partial removal of SPCR Ox while leaving the rest of the exposed oxide and other materials intact.

- Pre-epi wet clean step done with dHF /IPA drying on single wafer clean SNK does not meet cavity size WIW uniformity process specifications.

- Hence, a decision was made to transfer this critical clean step to a different wet clean vendor toolset, from Vendor A to Vendor B.
Improving WiW Uniformity: Adding BS N₂

- Adding N₂ to wafer backside in vendor B tool gave worse performance

- Need to change process/ hardware/ software settings in GO TO tool to ↓ WiW non-uniformity
Improving WiW Uniformity: Adding dHF on Wafer BS

- Had to increase FS dHF time to match removal in Vendor A tool
- Generating many BS particles with dHF only on wafer BS
Improving WiW Uniformity: Adding DIW on Wafer BS

- With FS dHF and BS DIW process, only process time needs to be dialed in to achieve target critical cavity dimension
BS dHF is generating excessive removal on wafer FS!
Improving WiW Uniformity: Adding DIW on Wafer BS + FS dHF scan
Final HVM Setting on Vendor B Tool

HVM LEARNINGS:

- Need to change process time to match critical cavity dimension achieved on Vendor A tool
- Adding BS flow makes WiW temperature uniform on wafer FS
- For wafer BS, recommend using DIW, than dHF, to prevent BS particle generation and center removal signature
- Need chemical dispense arm scan to minimize WiW non-uniformity
Summary

- DIO₃ based clean with upstream etch process changes gave the lowest C, O and F contamination levels on the XPS pad but does not reflect reality

- Developed a new pre-epi wet clean that:
  - $R_{on}$ (same measured for not shown transistor metrics such as DIBL, $I_{eff}$ etc.)
  - Cavity size is unchanged
  - ~ 50x ↓ in missing epi defects
  - Further optimization is in progress

- To meet cavity size WiW uniformity requirements, had to transfer wet clean process to new vendor SNK
  - Adding BS flow makes WiW temperature uniform on wafer FS
  - For wafer BS, recommend using DIW, than dHF, to prevent BS particle generation and center removal signature
  - Need chemical dispense arm scan to minimize WiW non-uniformity
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