Localised FIB Deprocessing on Advanced Process Technologies

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Background
What is Deprocessing?

• Deprocessing is the art to remove metal layers uniformly in an IC.

• Can be performed globally, by mechanical polishing, but the FIB offers the possibility to deprocess specific local regions, whilst retaining device functionality.
Why do we Deprocess?

• The requirement to access a particular layer of the device which is sub-surface.

• Once the layer is reached, further failure analysis (voltage contrast, defect analysis, electrical probing, reverse engineering) or circuit modification can be performed to achieve and end result.
The Mixed Field Problem
The mixed field Problem

The necessity to evenly mill through different materials with different milling rates introduces a significant challenge. Unpredictable copper grains’ orientation makes the problem even more complicated. Gas assisted etching is key for successful delayering.
Achieving Planarity

• One option is to use appropriate chemistries and beam parameters to achieve an even etch rate for different materials
Current Deprocessing Method
Current Deprocessing Methods

- Alternating of XeF2 assisted etch (for dielectric removal) and H2O assisted etch (for copper removal) is a well known and robust method that is used for “Cu + SiO2” and “Cu + LowK with SiN as an etch stop layer” mixed field planar de-layering. This method is fast and repeatable enough for past backend technologies.
Current Deprocessing Methods

Although, the “Old Method” provided a good solution for the past backend technologies, one problem was unavoidable. A layer of possibly conductive materials was always deposited on the trench sidewalls as a result of non-volatile materials sputtering.
The SiC roadblock
Requirements for Etch Stop Layer in Cu Damascene Processes

- Should have low k
- Be a good copper diffusion barrier
- High etch selectivity properties wrt to ILD
- Compatible with damascene processes
  - 1st Generation etch stop was SiN
  - However thick layer is required for etch selectivity
  - k value was 7.0
  - Overall k of dielectric stack was impacted
  - 2nd Generation etch stop is SiC
  - Better etch selectivity, thinner films possible
  - k value < 4 possible
SiC as an Etch Stop Layer

When it comes to “Cu + LowK with SiC as an etch stop layer” combination the “Old Method” is not suitable. H2O creates highly volatile compounds (COx) with carbon and therefore cannot be used for selective copper removal anymore.

The attempt to apply this method to “Cu + LowK with SiC as an etch stop layer” combination leads to uncontrollable etch of dielectric.
Planar Deprocessing with New Chemistry
Excellent planar deprocessing has been achieved on Cu-low k regions using new FEI chemistry.

None of the problems associated with XeF$_2$/H$_2$O and SiC are observed with clean removal of the SiC layer.

The process is slower than previously allowing the user more control over the deprocessing.
Planar Deprocessing Results
28 nm process

20 µm x 20 µm area delayered uniformly from M9 down to exposure of poly-silicon
Planar Deprocessing Results

22 nm process

20 µm x 20 µm area delayered uniformly down to M1
Planar Deprocessing Results

Reduced Redeposition using new chemistry

XeF$_2$/H$_2$O conventional delayering

New Chemistry delayering
Conclusions and Future Work

• Deprocessing/delaying is an important technique in failure analysis labs for various applications.
• Today’s aggressive technologies make it difficult to use existing methods to retain delayering planarity
• New Chemistry works extremely well for deprocessing/delaying in advanced process technologies which use SiC as an etch stop layer
• Is available in GIS format for single beam FIB and SDB systems
• Customer specific recipes provided by FEI
• Further chemistry work is underway to include delayering of Cu/SiO$_2$ regions with a single gas chemistry and a further reduction of redeposition
Thank You