NNCI ETCH WORKSHOP
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Chamber Wall Monitoring and Cleaning Strategies for Metal Etching

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What is the problem?

- Whenever we plasma etch, residue is formed on the chamber walls.
- Sources of the residue (organic or mineral based):
  1. plasma chemistry
  2. material being etched, byproducts (volatile or non-volatile)
  3. masking material (organic or inorganic)/resist coverage %
  4. chamber components (parasitics eg. clamp, dielectric window..)
- Chamber wall conditions affect plasma chemistry (time and process dependent). Walls originate as anodized aluminum→???
- Plasma chemistry determines the etch characteristics
  1. etch rate/profile control
  2. selectivity
  3. uniformity
  4. repeatability (run-to-run process drifts)

How to identify or characterize chamber coatings?

- The “Gap Technique” to simulate sample, sidewall, and chamber plasma exposure conditions. Ex-situ XPS analysis of the coatings in each of these regions.
- The residue on the chamber walls is often similar to that on the sidewall of the etched feature.
- Composition depends on the plasma chemistry, material etched, the etch mask, and the plasma conditions. “Memory effect”

“Gap Structure” for chamber wall & sidewall analysis

Plasma

30nm ALD Al2O3/Si

“Trench bottom”

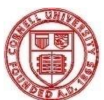
Metal layer

Base Si wafer

“chamber wall region”

“trench top”

L. Zheng, et.al., JVSTA, 23, 634 (2005)



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Tantalum Etching-deposited wall coatings

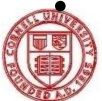
- Ta can be etched in fluorine, chlorine, or bromine chemistry.
- Etching with Cl_2 and PR mask produces CCl_x chamber coating.
- Etching with HBr and PR mask produces a CBr_x chamber coating.
- Etching with Cl_2/HBr produces a more dominant CCl_x coating due to preferential adsorption of Cl on C, while Br recombines to Br_2.
- Addition of O_2 removes the C but TaOCl forms due to the high reactivity of Ta with O.

Removal of Ta etch chamber coatings

- SF_6/O_2(15%) can remove carbonaceous layers CCl_x or CBr_x.
- SF_6/O_2 will not remove any oxidized Ta layers.
- Cl_2 can remove TaO_x but it is slow.
- SF_6/Cl_2 will remove TaO_x based coatings.
- Over etching in SF_6 will lead to AlF on the chamber walls-primary source of process drifts. Careful of too much of a good thing!
- Good news: $SiCl_4/Cl_2$ effectively removes TaO_x AND AlF leaving the chamber in the original anodized aluminum state.

Molybdenum etching and deposited wall coatings

- Mo can be etched in Cl and F based plasmas, with F being most reactive.
- When etched in pure Cl2, a MoClx coating is present and can form a sidewall deposit.
- When O2(10%) is added to Cl2, the etch rate is 6x higher due to enhanced volatility of MoOCl. Similar to the behavior of most group VI transition metals (Cr, W,..).
- Cl2/O2 is best choice for more anisotropic profiles.
- Very low etch rate in HBr due to non-volatile MoBr.
- Etches very well in SF6, CF4, CH2F2 with MoF6 produced.
- Adding O2 to F plasmas enhances ER by forming more volatile MoOxF.
- Formation of MoF6 is more reactive, but less volatile than MoOxF.
- The high reactivity of F plasmas can lead to more undercutting.



Removal of Mo based coatings from chamber walls

- SF_6/O_2 plasma removes MoF_x, MoCl, and MoOCl films.
- When etching with SF_6, there is a competition between formation of MoF and its removal.
- CF_4 will be less efficient in removal due to lower F concentrations.
- Remember excessive SF_6 plasma cleans can lead to AlF formation.
- Good news! $SiCl_4/Cl_2$ can effectively remove AlF deposits.

Tungsten etching and deposited wall coatings

- W can be etched in F, Cl, and Br based plasmas, but with much different efficiencies.
- Etch rate in F plasmas is highest, while the rate in HBr is the lowest.
- Volatility of $WF_6 > WCl_6 > WBr_6$.
- SF_6 leaves no detectable W residue on the walls.
- Cl_2 and HBr can deposit WCl_x or WBr_x coatings.
- Most of the deposits can be removed with F or Cl based plasmas.
- SF_6/O_2 is the most efficient due to very high volatility of WF_6.

Ti etching and chamber deposits

- Ti can be reliably etched in Cl_2, HBr, HBr/Cl_2.
- $TiCl_x$ and $TiBr_x$ etch products are volatile, with $TiCl_4$ being most volatile.
- Avoid etching Ti in F-chemistry due to the non-volatile TiF_x formation.
- TiO_2 including native oxide layers can be etched in F-chemistry.
- HBr or Cl_2 based etch may produce a thin TiBr or TiCl chamber wall deposit due to the volatile nature of these products. Deposits are also etched back into the plasma by reacting with atomic Cl or Br.
- Problem occurs when O_2 is added or is present by mask erosion or other parasitic sources → thick TiOCl or TiOBr oxygen-rich deposits.

Removal of Ti deposits from the chamber walls

- To remove any thin TiBr or TiCl deposits, run a Cl_2 plasma to effectively volatize them.
- The thicker TiOCl or TiOBr deposits cannot be removed in either a Cl_2 or HBr plasma due to the high bond strength of Ti-O.
- To effectively remove any oxidized Ti deposits, an SF_6/O_2 plasma is the best candidate.
- Bigger problem when etching advanced gate stacks such as polysilicon /TiN/HfO_2 → stack of deposits which then may require a multi-step plasma clean strategy.

Mechanisms for chamber wall deposits

- The dissociation, ionization, and diffusion times to the chamber walls is much shorter than the residence times in the chamber (even for high flows).
- So any etch bi-products will undergo several collisions with the chamber walls before being pumped out.
- Non-volatile species will stick on the walls with high probability.
- Even volatile species can be rapidly dissociated/ionized to form non-volatile deposits on the walls.
- As the reactor wall conditions change from wafer to wafer, so does the surface reaction probability change and it may lessen the production of reactive species leading to process drifts.