NNCI ETCH WORKSHOP
Virtual Meeting
December 9, 2020

Chamber Wall Monitoring and Cleaning Strategies for Cl and Br Based Si Etching

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Outline

- Problem/Motivation
- Background information
- Strategies and solutions

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-parasitic (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
  2. selectivity
  3. uniformity
  4. repeatability (run-to-run process drifts)

Characteristics of Cl2 and HBr etching of Si

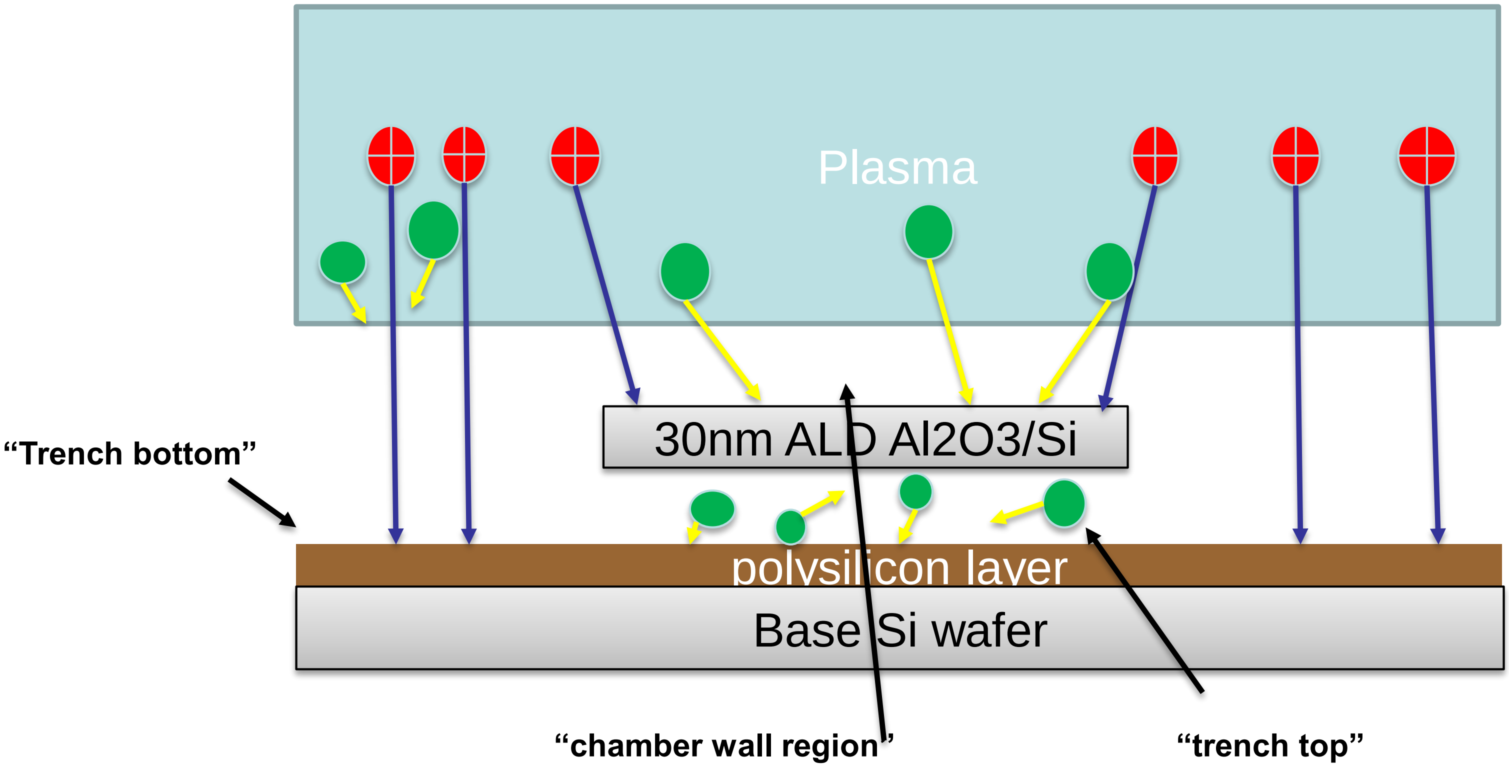
- Both Cl and Br have high recombination rates.
- Radical concentrations depend on these recombination rates.
- Recombination largely takes place at the chamber walls.
- Seasoned chambers have a stable chamber coating of SiOCl or SiOBr which inhibits recombination (ie. Loss of radicals)
- Density of Cl and Br radicals is maximized in a well seasoned chamber, where recombination is minimized.
- Sidewall passivations of SiOCl and SiOBr determine the etch profile evolution.
- Stable and consistent chamber conditions lead to reproducible etch results.
- 60% decrease in Br and Cl concentrations in a bare Al2O3 chamber than in a seasoned chamber→lower etch rates & poor profiles.

How to monitor chamber conditions?

- In-situ methods:
  1. optical emission spectroscopy (OES): real time, run-to-run.
  2. FTIR (most of us don't have this as a practical option).
  3. XPS (quasi-in-situ, multi-chamber system).

- The "Gap Technique" to simulate sample, sidewall, and chamber plasma exposure conditions. Ex-situ XPS analysis of the coatings in each of these regions.
- To remove the residue, you must first identify it.
- Composition depends on the plasma chemistry, material etched, and the plasma conditions.

“Gap Structure” for chamber wall and sidewall analysis



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

What types of coatings are we dealing with?

- Silicon etch with:
  1. Cl_2: $SiCl_x$ or SiOCl (oxygen from mask or chamber parasitics)
  2. HBr: $SiBr_x$ or SiOBr
  3. HBr/Cl_2/O_2: SiOCl(Br) dominated by Cl due to competitive adsorption.
  4. higher O_2% → SiO_x due to halogen substitution by oxygen which can release Cl or Br to the plasma.

- Silicon etch with large area of resist masking:
  1. SiOCl(Br) → SiOCl(C)(Br) → CCl_x

How can gas additives influence chamber coatings?

- Addition of CF_4 to $HBr/Cl_2/O_2$:
  1. considerably reduces the amount of SiOCl on the walls. (good)
  2. increases the MTBC (good)
  3. reduces the etch rate due to competitive mechanisms (bad)
  4. can change the profile evolution, loss of CD (bad)
  5. will reduce the selectivity to PR.

- Different amounts of CF_4?
  1. low CF_4/O_2 ratio → SiOCl (albeit lesser amounts)
  2. CF_4/O_2=4:1 → no SiOCl on the walls (not necessarily good)
  3. high CF_4/O_2 → carbonaceous film deposit with low F content due to silicon loading and H scavenging of F due to the HBr.

How can gas additives influence chamber coatings?

- Addition of O_2:

1. small amount (< 5sccm) enough to prevent C deposition and possibly avoid oxidation of SiCl or SiBr.
2. more PR coverage lessens the amount of SiOCl or SiOBr.
3. more PR coverage induces formation of involatile CCl_x and C on the walls.
4. higher amounts induce oxidation of SiCl, SiBr forming SiOCl or SiOBr. Could be mitigated by an appropriate level of CF_4.

Proposed solutions for chamber cleaning

- Oxygen plasma clean: removal of carbonaceous deposits from PR and some halogen (F) removal.

  O_2/Ar = 50/5sccm, 2500W(ICP)/25W(RIE), 5mtorr.

- SF_6 plasma clean: removal of SiOCl and SiOBr

  SF_6/O_2/Ar = 50/10/10sccm, 2000W(ICP)/50W(RIE) 10mtorr.

- You must remember to re-season the chamber to baseline your process every time for run-to-run consistency.