Chamber Clean/ Conditioning for III-V Etching

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Purpose

- Why do we need chamber clean and conditioning?
- Do we need both clean and condition?

Chamber Clean / Conditioning

- When do we do it?
- How often?
- For how long?

Factors in choosing a clean / conditioning process

- What are the options?
- How to choose the right process?
- How to verify?
Chamber Clean & Conditioning - Purpose

Why?
- Chamber warmup
- Maintain chamber condition
- Process reproducibility
- Defect reduction

How does chamber condition change?
- Etch by products absorbed on chamber walls
  - Volatility of the by products
  - Sticking coefficient
  - Chamber wall temperature
  - Surface conditions
- Outgassing from the chamber walls
  - Can participate in the reactions in the chamber
  - Materials from the chamber wall can also be redeposited on the exposed surfaces
- Reactants can be absorbed / consumed by the material in the chamber walls.
- Plasma generates heat and as processes are run, the chamber warms up and reaches a steady temperature
Chamber Warm Up Effect

Real-time etch control to reduce first wafer effect in SF6/O2/Ar plasma, S. Ryu et al., 2018
International Symposium on Semiconductor Manufacturing,

Chamber Clean & Conditioning Options

Types of Clean / Condition Processes

• Waferless clean (typically run under production settings) / Condition
  • Short process run between wafers without wafer on the chuck
  • Depends on the equipment
  • Possible in ICP etchers
  • Should be run without backside Helium or bias power as electrode material should not be damaged

• Between wafers with a wafer on the chuck
  • Run like a regular process but with a seasoning wafer
  • Recipe may be different from the one used for substrate processing
  • Between different etches – To remove material from previous processing and restoring chamber condition for current process

• Before opening the chamber –
  • To minimize exposure to volatile/ toxic by products on the chamber walls

• Chamber wet clean
• After wet clean to restore chamber condition for substrate processing
Factors in choosing a clean / conditioning process –

• Type of residue to be removed
  • Material deposited by previous processing and chamber conditioning
• Type of surface exposed during cleans
  • Typically, chamber walls are made of anodized aluminum (Al₂O₃) which is resistant to many chemistries especially since the chamber walls are grounded and hence minimal ion bombardment
  • Other materials exposed are the clamp ring, chamber liner wafer used for clean/ conditioning –
    • Ceramic, Quartz, Silicon
• Ability to remove residues and contaminants –
  • Chemistry selection
  • Optical end pointing
• Restoring chamber condition
  • Type of wafer used for clean and condition (silicon wafer, sapphire wafer, resist coated wafer etc)
  • Chemistry
Impact of Chamber Clean & Conditioning

GaAs Etch Rate - Without Chamber Clean or Conditioning

GaAs Etch Rate - After Chamber Clean & Conditioning – No clean/ conditioning between wafers

Effect of Chamber Clean and Conditioning on InP Etch

III-V Etcher – Materials Etched and Processes

GaAs
• Cl2/ BCl3/Ar
• Typical chuck temp – 20-40 °C

GaN/ AlGaN...
• Cl2/ BCl3, Cl2/ Ar
• 20-40 °C

InP/ InSb...
• Cl2/CH4/H2/Ar
• 20-40 °C

ITO Etch
• CH4/H2
• 20-40 °C

Diamond
• O2 chemistry; other additives, Ar, SF6 or Cl2
• 300-400 °C
Three step Chamber Clean Process

Cl2/ BCl3, Cl2/Ar clean –
• To remove material that can form volatile by products

SF6/O2 or NF3/ O2 Clean -
• Removes chlorine from surface
• Useful in particle reduction
• Preferable to use wafers with SiO2

O2 Plasma Clean –
• Before and after chamber wet clean (can be done independent of other cleans)
  • Used in case of diamond etch and CH4/H2 etches.
• Removing organics
• Minimizes the presence of corrosive species on chamber walls
• Can be done with any type of wafer
• If resist coated wafer is used,
  • A thin polymeric film will be deposited on the chamber walls
  • Shields the chamber wall material exposure during run

Chamber Conditioning – with process chemistry

Three Step Chamber Clean Recipe at Stanford:

1. 20mT/ 10 BCl3/ 20 Cl2/ 10 Ar/ 1500 ICP/ 50 BP/5min
2. 20mT/20 SF6/100 O2/ 2000 ICP/ 50 BP/ 5min
3. 20mT/100 O2/1500 ICP/ 50 BP/ 5 min

Clean Silicon wafers are used for convenience.