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nano@stanford

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Chamber Clean/ Conditioning for III-V Etching

Usha Raghuram

Stanford Nanofabrication Facility

Stanford University

Chamber Clean & Conditioning in Etchers - Overview

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?

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Chamber Clean & Conditioning - Purpose

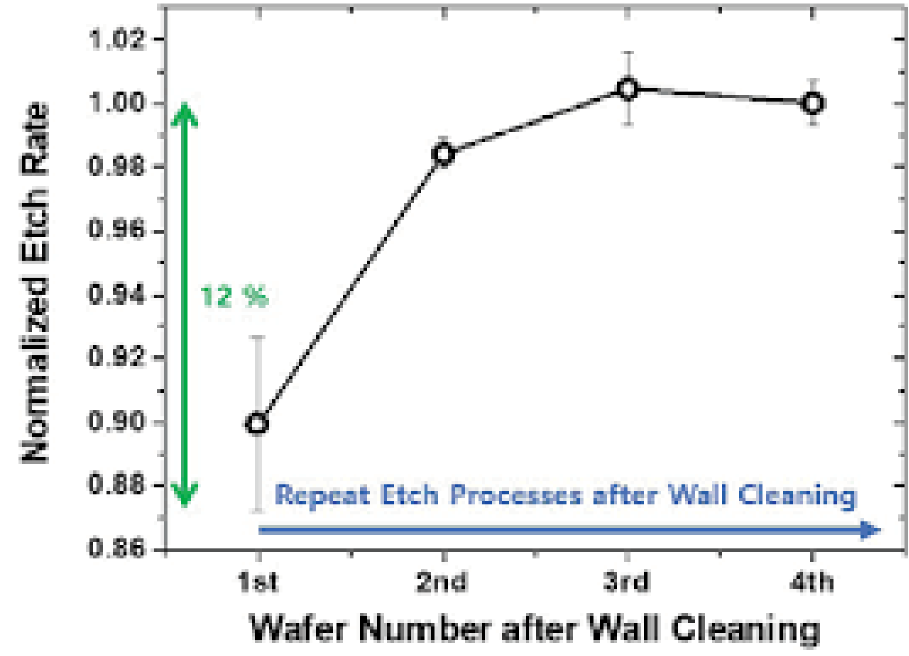
Why?

- 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



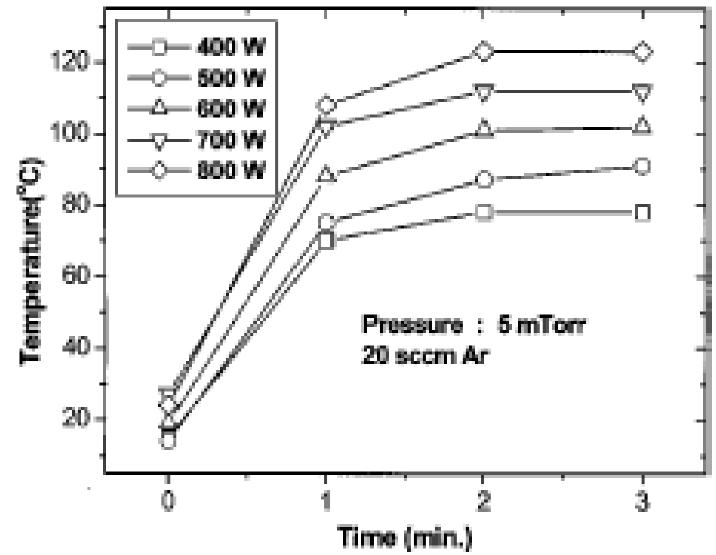


Fig. 8. Wafer temperature as a function of time in Ar plasma.

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

Heat Transfer between wafer and electrode in a high-density plasma etcher, Korean J. Chem Eng., Vol 19, p.347, 2002

Chamber Clean & Conditioning Options

Types of Clean / Condition Processes

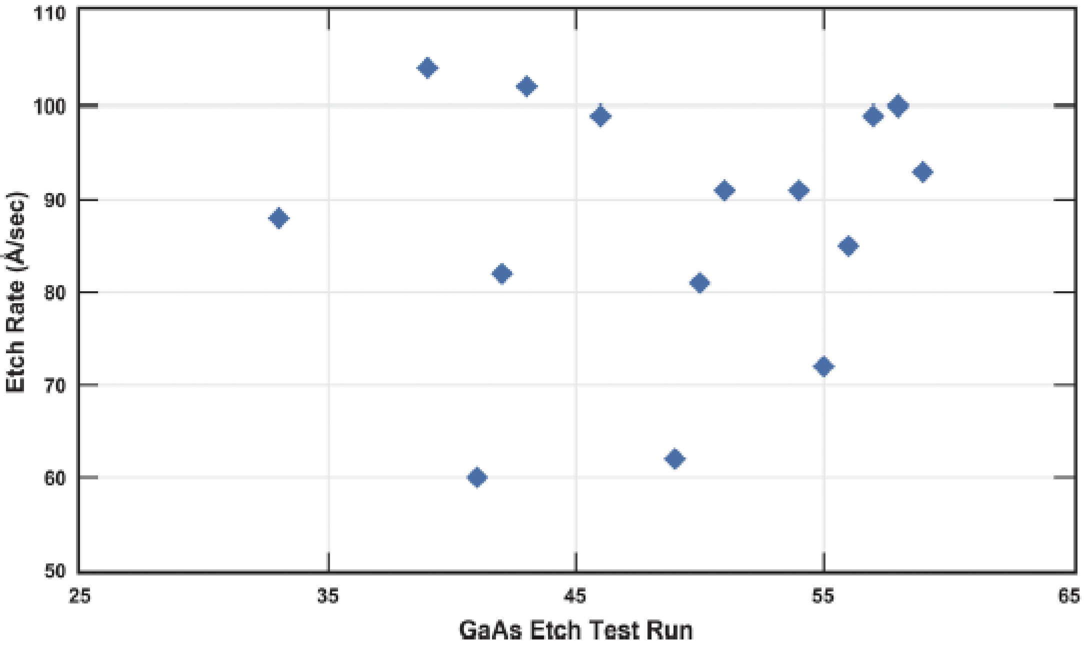
- Waferless clean (typically run under production settings) / Condition
    - Short process run between wafers without wafer on the chuck
    - Depends on the equipment
    - Possible in ICP etchers
    - Should be run without backside Helium or bias power as electrode material should not be damaged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

Chamber Clean & Conditioning

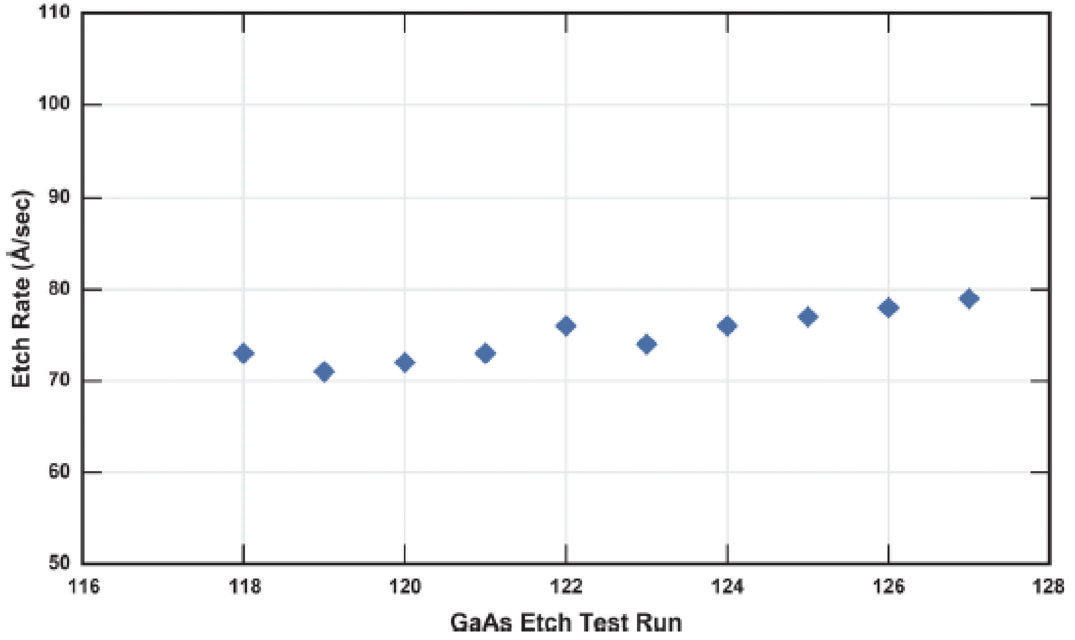
Factors in choosing a clean / conditioning process –

- 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 (Al_2O_3) 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



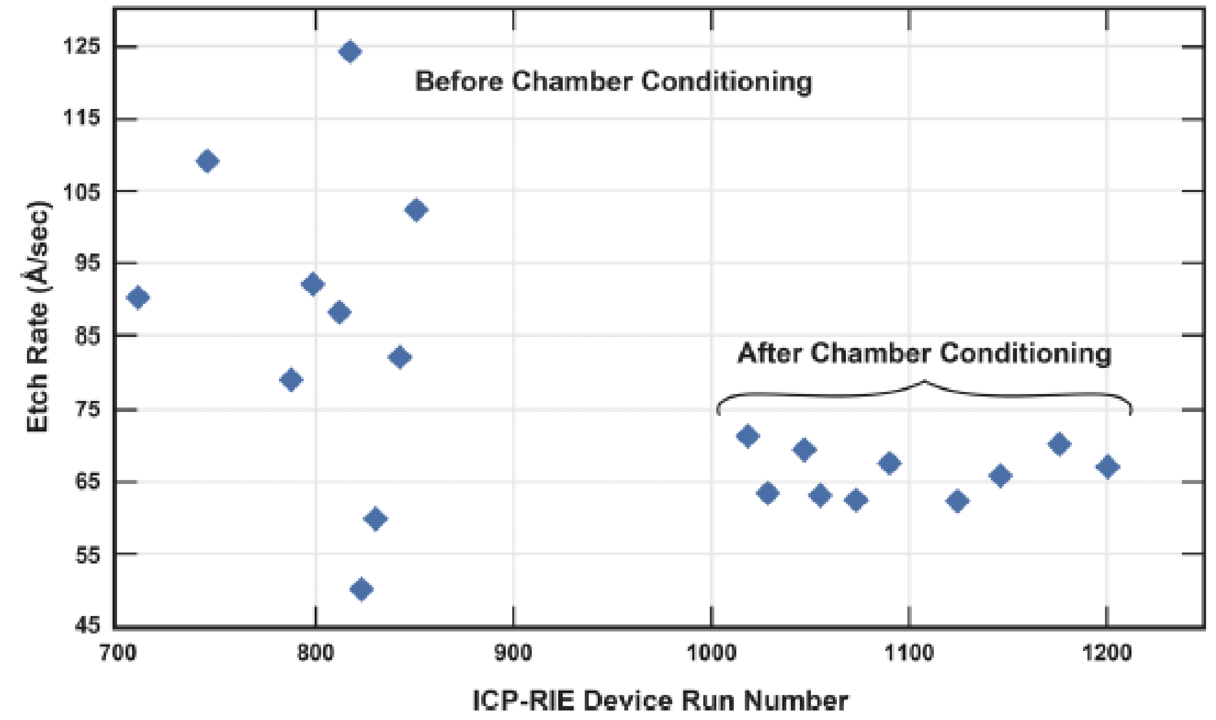
GaAs Etch Rate - Without Chamber Clean or Conditioning



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

Chamber conditioning process development for Improved inductively coupled plasma reactive ion etching of GaAs/ AlGaAs materials, Michael K. Conners, Jason J. Plant, Kevin G. Ray, and George W. Turner, J. Vac. Sci. Technol., B31, 021207 (2013)

Chamber Clean & Conditioning



Effect of Chamber Clean and Conditioning on InP Etch

Chamber conditioning process development for Improved inductively coupled plasma reactive ion etching of GaAs/ AlGaAs materials, Michael K. Conners, Jason J. Plant, Kevin G. Ray, and George W. Turner, J. Vac. Sci. Technol., B31, 021207 (2013)

Chamber Clean & Conditioning

TABLE II. Chamber clean etch step-by-step process details.

Step	Time (min)	Pressure (Pa)	Bias (W)	ICP (W)	Gas	Flow (SCCM)	Gas	Flow (SCCM)
1	60	8.0	50	500	Cl_2	20	Ar	50
2	120	8.0	50	500	CHF_3	10	O_2	50
3	60	8.0	50	500	Ar	10	O_2	50
4	60	1.0	50	500	Ar	10	O_2	50
5	15	5.0	50	500	Ar	100		
6	30	10.0	50	300	Cl_2	20	Ar	50

Chamber conditioning process development for Improved inductively coupled plasma reactive ion etching of GaAs/ AlGaAs materials, Michael K. Conners, Jason J. Plant, Kevin G. Ray, and George W. Turner, J. Vac. Sci. Technol., B31, 021207 (2013)

III-V Etcher – Materials Etched and Processes

GaAs

- Cl_2/ BCl_3/Ar
- Typical chuck temp – 20-40 °C

GaN/ AlGaN…

- Cl_2/ BCl_3, Cl_2/ Ar
- 20-40 °C

InP/ InSb…

- Cl_2/CH_4/H_2/Ar
- 20-40 °C

ITO Etch

- CH_4/H_2
- 20-40 °C

Diamond

- O_2 chemistry; other additives, Ar, SF_6 or Cl_2
- 300-400 °C

Chamber Plasma Clean

Three step Chamber Clean Process

Cl_2/ BCl_3, Cl_2/Ar clean –

- To remove material that can form volatile by products

SF_6/O_2 or NF_3/ O_2 Clean -

- Removes chlorine from surface
- Useful in particle reduction
- Preferable to use wafers with SiO_2

O_2 Plasma Clean –

- Before and after chamber wet clean (can be done independent of other cleans)
  - Used in case of diamond etch and CH_4/H_2 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 BCl_3/ 20 Cl_2/ 10 Ar/ 1500 ICP/ 50 BP/5min
2. 20mT/20 SF_6/100 O_2/ 2000 ICP/ 50 BP/ 5min
3. 20mT/100 O_2/1500 ICP/ 50 BP/ 5 min

Clean Silicon wafers are used for convenience.