Chamber Matching at Sputter Clean Chambers with Inductively Coupled Plasma

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Content

- Sputter etch process – pre clean before sputter deposition
- Inductively coupled plasma
- Chamber matching and RF power losses
- Detection of chamber matching problems using plasma metrology
Sputter etch process – pre clean before sputter deposition

- Air (oxygen) in contact holes leads to increased contact resistance.
- Sputter etch process for cleaning and oxide removing.
- Small etch rate and small ion energy (radiation damages in silicon crystal for higher ion energy).
- Low process pressure is recommended (redeposition, reoxidation is possible by higher process pressure).
- The plasma process is near at the pressure limit.

Inductive coupled plasma:
- High ion density and small ion energy.
- Separate ion energy control by bias power.
Salicide process

- Surface cleanliness before deposition is extremely important
- The native oxide can be removed with a wet dip but this limits the queue time between the dip and metal deposition
- An in-situ sputter clean provides more flexibility in terms of the queue time.
- The amount of sputter clean required is between 25-50Å of oxide

Too short:
- insufficient pre clean -> CoSi-Spiking

Too long:
- re-sputtered Si on spacer wall
- CoSi growth where not wanted
- Si can be removed in next step but not CoSi

- Ar-Plasma
Situation in 2009

- Process control
  - Daily check on thermal oxide
  - Oxide etch removal 5nm

- Impact on products
  - Different etch rates cause yield loss and parameter shift based on product design
  - Etch chambers had to be blocked for certain products

![Graph showing oxide etch removal and BLBL leakage](image)

BLBL leakage depends on sputter depth
Cold Soft Etch chamber

Preclean chamber with two different RF couplings:

- Inductive coupling (ICP, inductively coupled plasma) for plasma generation
- Capacitive coupling for BIAS control (etch)

![RF-system of CSE-chamber diagram]
Inductive coupled plasma – 2 main problems

1. Plasma mode: E and H mode
   - Every ICP plasma ignites in E mode!
   - If the ICP power is high enough to yield a high electron plasma density, the plasma switches to H mode.
   - If RF losses are too high, the plasma remains in E mode.

2. Phase angle
   - Two generators with the same frequency (13.56 MHz).
   - Capacitively coupling from ‘hot’ end of coil and electrode (Chuck).
   - Phase angle difference affects sheath potentials and ion energy at wafer.
   - The ion energy affects etch (sputter) rate and crystal damages.
1. Ignition, E and H mode

- RF Switch on:
  - High $U_0 \rightarrow$ Ignition in E-mode

- Low RF power:
  - High $R_{\text{bulk}} \rightarrow$ Low $i_{\text{coil}_s}$
  - High $U_0 \rightarrow$ Plasma in E-mode

- High RF power:
  - Low $R_{\text{bulk}} \rightarrow$ High $i_{\text{coil}_s}$
  - Low $U_0 \rightarrow$ Plasma in H-mode

E-mode $\rightarrow$ capacitively coupled  H-mode $\rightarrow$ inductively coupled
Chamber matching and RF power losses

- Main reason for undefined plasma mode: RF power losses
- In case of high ICP-power losses the plasma remains in the E-mode.
- RF power losses depended on:
  - Aging of RF parts
    - Contacts
    - Eddy currents
    - Ceramic
  - Second source parts
  - Chamber improvement
  - Matchbox (new / old)
The effect of ICP mode at the chamber check

- Process control by etch rate of test wafers

- Sputter etch process:
  Etch rate depends on ion energy and ion current.
  \[ E_H \cdot j_{+H} = E_E \cdot j_{+E} \]

  - \( E_H \) – ion energy for H - mode
  - \( E_E \) – ion energy for E - mode
  - \( j_{+H} \) – ion current for H - mode
  - \( j_{+E} \) – ion current for E - mode

- E – mode: small ion density, but high ion energy, \( \rightarrow \) high radiation crystal damages!

- H – mode: high ion density, but small ion energy

- Etch rate can be similar, chamber seems to be in spec!
2. phase angle

- Capacitive coupling through dielectric window (about 2/3 of power inductively about 1/3 of power capacitively)

- Phase angle between upper and lower capacitive coupling affects sheath potentials and ion energy!

→ Generator synchronization
Synchronisation RF-coupling

- Stable and comparable parameters seen with RF-configuration at 180°
- Electron and ion densities depend on phase angle.
- Ion current depends on phase angle.

Interaction of 2 electric fields with the same frequency
- Sheath voltage depends on phase angle.
- Ion energy depends on sheath voltage.

Adjustable movement dependent from:
- coax cable length
- Adjustment Sync Switch Box

Sync Switch Box - Matrix
- Adjustment per 1/32λ
- 1 Period

Summary

- Optimized RF-Setup

  - Cable length coaxial cable \(1\lambda = 14.58\text{m}\)
  - Synchronously RF-coupling \(168.75^\circ\)
  - Matching control adjustments
    - ICP: Load 47\(\Omega\), Tune 47\(\Omega\)
    - BIAS: Load 220\(\Omega\), Tune 100\(\Omega\)
  - Auto matching ON

- Only certain RF-power input enables stable plasma in H-mode.
- Well-defined phase angle at chamber provides well defined plasma parameters and etch rate.
Results

- all Low-Power CSE-chambers are comparable
- no more significant differences in etch rate

- comparable HERCULES®-data of all our chambers, also comparable for APC-analysis
- defined RF-Setup, no subjective adjustments