Maintenance and Optimization of Aviza HSE Sputter Etch Chamber

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Outline:

• Process issue and understanding
• RF characterization of chamber parts
• Failure Analyses
• Solution by RF system refurbishment
• Results - Failure statistic
• Summary
Process Issues: Reflected Power Warnings / Aborts …

- Our Aviza Hot Sputter Etch chamber (HSE) frequently suffered from:
  - Platen RF Reflected Power Warnings/ or Aborts

- Accompanied by instable etch plasmas and therefore
  - Platen RF DC Bias Warnings/ or Aborts
Arcing...

- Opened Chambers showed signs of Arcing
  - On the chamber lid
  - Or in strong cases even black residuals on the chamber walls
  - Resulting in increased DD and single wafer Scrap
Chamber Setup - Phase Angle – How it works

• Synchronization of coil and platen generator:
Why is the Phase Angle important for the Etch Rate & Damage?

• Phase Angle between Coil and Platen impacts
  • Bias voltage → Ion energy → Etch rate & Damage

*measured by TI – recalculated with corrected values*
Why is the Phase Angle Important for Process Stability?

- RF Hardware stability $\rightarrow$ RF current in chamber $\rightarrow$ Process stability
- Stable Wafer RF current $\rightarrow$ ion energy $\rightarrow$ etch rate $\rightarrow$ no big influence
- High RF current variations at chamber lid $\rightarrow$ Process instability, ignition problems, aborts, arcing …
RF Characterization of Chamber Parts

• The main Principle
• Generators
• Phase shifter (SSB = Synchron Switch Box)
• Entire system
Phase Angle – How it works

- Synchronization of coil and platen generator:
What is needed for stable RF Hardware and Process?

- The control signal from the Master Generator (CEX OUT) must be well defined in shape and phase angle: ideally a rectangular signal.

- Transmission of the control signal must not influence neither shape nor phase significantly.

- The Slave Generator must use the input signal (CEX IN) correctly.
The ideal shape of the control signal should be a rectangular signal. This signals are recorded with dummy loads - real loads are even worse. Possible reason: Generator aging.

*Measurement Equipment used: Digital 500 MHz Scope HP 54615A with various hf probes.*
Generator: Phase Variance of Control Signals

• The shown variance in the control signal referred to RF power output is directly transferred to the same phase variance at the chamber! *The tool offers adjustment in steps of 11°!*

• Any change of a generator can lead to a nonfunctional chamber as often experienced.

*Measurement:*  
**Falling edge of power output to falling edge of control signal.**

![Generator influence on control signal](image)
SSB = Synchron Switch Box

- The SSB is designed to delay the control signal (=phase shifter);
  - With dip switches cables of different length are combined
  - It offers adjustments in increments of 11.25°
Poor Transmission due to Signal Reflections at Switches inside the SSB 1 (= Synchron Switch Box 1)

**Issue:**
Signal reflections at end of feed cable and multiple ones inside at switches …

**Reflections lead to bad signal transmission and so to phase deviations!**
…. **SSB 2** (= Synchron Switch Box 2)

**Issue:**
Signal reflections at end of feed cable and multiple ones inside at switches …

**Reflections lead to bad signal transmission and so to phase deviations!**
Control Signal before and after SSB

• Each SSB modulates the control signal differently!

Control signals

Before SSB:  After SSB:

![Graphs showing control signals before and after SSB for Tools 1, 2, and 3.]
Worse Control Signals when SSB is connected to CEX OUT of Coil Generator

Phase angle between coil control signal and Platen RF power output (falling edge to falling edge)
Total Phase Variance of three Chambers

- Phase deviations of Generators alone
- Total phase from two measurements = (control signal – output of coil generator) + (platen output – control signal)

- Test conditions: BKM recipe, 400W platen, 300 W coil, Ar
- Range of phase error: 56°
- Can lead to different process results and unstable process (aborts).

Phase error finally depends on the combination of generator, SSB, and SSB adjustment.
Basline State – Failure Analysis (Summary)

Problem #1: poor control signal on CEX OUT Master

Problem #2: degraded control signal behind synchron switch box

Problem #3: each SSB modulates the signal differently

Problem #4: 0° or 180° phase-shift on CEX IN

Master: Coil RF Generator 13,56 MHz

Slave: Platen RF Generator 13,56 MHz

Sync Switch Box = phase shifter

Coax 50 Ohm

Argon line

Plasma

Coil

Wafer

Chuck

Cryo pump

Platen Match

Coil Match
Solution by Refurbishment of RF System

• Implementation of external Master Oscillator with stable and good shaped control signal

• Change the generator synchronization from Master/Slave to Slave/Slave

• Exchange of the SSB with fixed phase delay RF cable of defined length
Solution by Refurbishment of RF System

Master oscillator 13,56 MHz

Slave: Coil RF Generator 13,56 MHz

Slave: Platen RF Generator 13,56 MHz

Coax 50 Ohm

Phase shift cable

Argon line

Coil Match

Coil

Wafer

Chuck

Cryo pump

Plasma

Platen Match

Plasma Metrology Experience

Texas Instruments
Pilot Chamber – Increased Stability

• **Current Status:** One chamber setup modified, comparing baseline to modification (on high utilization).

• **Baseline:** 115 warnings / 6 aborts in 8 weeks
  – mostly due to high reflected power.

• **Modified Chamber:** 0 warnings and 0 aborts in 8 weeks.
Summary

• **Issue:** Aging of generators, low quality of cables, and switches in phase shifter leads to unstable synchronization of coil and platen generator. Range observed at three chambers: 55°.

• **This results in risk of:**
  – Process aborts / scrap
  – Chamber down after generator is changed
  – Decreased uptime and OEE and increase of work load and costs of repair

• **Solution:**
  – Control by external master control signal generators
  – Replacement of all SSBs by customized cable set
  – Test method already verified