Development of a Plasma Etch In-situ Chamber Clean (ICC) and Analysis of Etch Plasma Problems using a SEERS Plasma Sensor

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Motivation

• TEXAS INSTRUMENTS wafer FAB (Freising/Germany) has been using the HERCULES SEERS plasma sensor from PLASMETREX since 2011

• SEERS* sensor - used for process monitoring & controlling of Barc Poly Etch, STI and DT plasma etch tools

SEERS* sensor: extended usage in 2012

➢ development / adjustment of insitu chamber clean (ICC) recipe more efficiently at Applied Materials Centura DPS+ multi process etch chamber

➢ investigation of occurring process problems at DT etch

*) SEERS: ‘Self Excited Electron Resonance Spectroscopy’

SEERS is a electrodynamic method for determination of absolute plasma parameters
SEERS usage at etch process investigations

- Barc / Poly Etch @ AMAT DPS+ Poly Chamber
  - Insitu Chamber Clean (ICC) development and characterization
    - old status: process interaction without ICC
    - ICC development
    - new status: process interaction with ICC

- Very Deep Trench Etch @ AMAT DPS DT Chamber
  - Problem detection and verification
    - Chamber miss-conditioning
    - Bias generator problem
ICC Development and Characterization

Old status:
process interactions without Insitu Chamber Clean (ICC)
Process interaction on Gate Poly Etch

Problem: optical endpoint intensity varies in dependency to prior etch process and its etch chemistry

Example: Gate Poly Etch (Barc and Poly stack)
-> Barc endpoint issues (O2/HBr) after preceding fluorine based processes
Process interaction on Gate Poly Etch

[optical emission: Barc Endpoint]

1. Barc Endpoint curve after prior Fluorine based Barc Etch Process
2. Barc Endpoint of Barc Poly Etch after prior Barc Poly Etch (Cl2/HBr/O2)
3. Problems with EP detection
4. EP Time stability
5. EP detectability

6. Barc Endpoint curve after prior Fluorine based Emitter Poly-Nitride Process

7. Barc Endpoint of Barc Poly Etch after prior Barc Poly Etch (Cl2/HBr/O2)

8. Barc Endpoint curve after prior Fluorine based Barc Etch Process
Process interaction on Gate Poly Etch

[SEERS: plasma parameter RF current]

Changes in Barc etch plasma, induced by prior process

--> visible in RF-current measured by Hercules Sensor

4 Barc/Poly Etch-Wafer:

5: post fluorine Barc Etch
6: post same B/P Etch
7: post same B/P Etch
10: nach NEMIT Poly Etch

HBr/O2 based Barc Etch

--> big impact from fluorine based preceding Etches

Time [s] | RF Current
---|---
0.0  | 
50.0 | 
100.0 | 
150.0 | 
200.0 | 
250.0 | 
300.0 | 
350.0 | 

AMAT-DPS 200mm WAC
effective_length=71.982
electrode_gap=115.000

ini-file of last wafer
Process interaction on Emitter Poly Etch

Problem: optical endpoint curve inclination varies in dependency to prior etch process and its etch chemistry

Example 2: Emitter Poly Etch (Poly, no Barc)

-> Poly main etch endpoint issues after preceding Barc-Poly etch processes
Process interaction on Emitter Etch
[optical emission: Poly Endpoint]

Risk of wrong detected Endpoints
Process interaction on Emitter Etch
(SEERS: plasma parameter RF current)

Changes in BT- and Poly etch plasma --> visible in RF-Current
Cl2/ HBr/ O2 based etch process
--> big impact on succeeding etch process with nearly same etch chemistry
Process interaction on DT Barc Etch

Problem: optical endpoint curve inclination and intensity drop varies in dependency to prior etch process and its etch chemistry

Example 3: DT Barc Etch (Barc only, C2F6) -> slight Barc endpoint variances after preceding Barc etch processes (N2/O2)

<table>
<thead>
<tr>
<th>Slot</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DUV BARC Etchrate Test</td>
</tr>
<tr>
<td>2</td>
<td>Xi-RI BARC Etchrate Test</td>
</tr>
<tr>
<td>3</td>
<td>DUV BARC Etchrate Test</td>
</tr>
<tr>
<td>4</td>
<td>DUV BARC Etchrate Test</td>
</tr>
<tr>
<td>5</td>
<td>Barc Poly Etch (L3C7-UV)</td>
</tr>
<tr>
<td>6</td>
<td>Barc Poly Etch (L3C7-UV)</td>
</tr>
<tr>
<td>7</td>
<td>Barc Poly Etch (L3C7-UV)</td>
</tr>
<tr>
<td>8</td>
<td>NEMIT Poly Etch (copy CEN17C)</td>
</tr>
<tr>
<td>9</td>
<td>NEMIT Poly Etch (copy CEN17C)</td>
</tr>
<tr>
<td>10</td>
<td>Barc Poly Etch (L3C7-UV)</td>
</tr>
<tr>
<td>11</td>
<td>NEMIT Poly Etch (copy CEN17C)</td>
</tr>
<tr>
<td>12</td>
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</tr>
<tr>
<td>13</td>
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</tr>
<tr>
<td>14</td>
<td>DUV BARC Etchrate Test</td>
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<td>DUV BARC Etchrate Test</td>
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<tr>
<td>16</td>
<td>DUV BARC Etchrate Test</td>
</tr>
<tr>
<td>17</td>
<td>DUV BARC Etchrate Test</td>
</tr>
</tbody>
</table>
Process interaction on DT Barc Etch
[optical emission: Barc Endpoint]

Fluorine based DT Barc Etch -> slight impact from N2/O2 Barc Etch

→ slight variances in Endpoint traces and Etch Rate
Process interaction on Emitter Etch

[SEERS: plasma parameter RF current]

Fluorine based DT Barc Etch

--> light impact from N2/O2 Barc Etch at beginning of etch step

7 DT Barc Etch Wafer:

red (#1) and blue (#3): both wafer post prior Barc Etch only (N2/O2)

#14 (light green) post EMIT Poly Etch (Cl2/HBr/O2)

all other Wafer post same DT Barc Etch (C2F6)
Process interaction on DT Barc Etch
[process parameter: Barc Etch Rate]

- BARC-only Etch process (DUV/I-line) show self conditioning effect for its own etch rate
- ER decreases from wafer to wafer and gets stable after a few runs

→ 1\textsuperscript{st} Wafer effect, respectively a first-five-Wafer effect
   generates problems especially on Fixed Time Etch processes
ICC Development and Characterization

Development of a suitable Insitu Chamber Clean (ICC)
Development of Clean Etch Process (ICC)

ICC Setup → 4 Step process:

- Plasma Strike
- High Pressure Clean
  (remove Poly-, Oxide-, Nitride-Etch byproducts)
- Transition step
- Low Pressure Clean
  (remove organic resist etch-byproducts)
Development of Clean Etch Process (ICC)

[SEERS: plasma parameter collision rate]

Overlay Collision Rate traces of ICC process post all used Etch processes:

- Collision Rate shows plasma changes during ICC Clean process clearly.
- Plasma Collision rate during etch depends on preceding process.
- Saturation of collision rate trace during high pressure clean show finished clean process!
- ICC post most of the etch processes show Clean-End after ~10sec in high pressure step.
- Exception: ICC Clean post Barc Poly Etch process needs significantly more time to clean the chamber!
Development of Clean Etch Process (ICC)

[SEERS: plasma parameter collision rate]

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- **Gate Poly Etch needs longer ‘high pressure clean’ step**
- **Finished cleaning is visible in saturated curve**

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**ICC optimization for Barc Poly Etch processes** → prolong the ‘high pressure clean’ step

- **Red and blue curve:**
  - hp-clean 25sec
  - no curve saturation
  - chamber clean not finished

- **Green curve:**
  - hp-clean 40sec
  - curve saturation reached
  - chamber clean finished

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Use of SEERS plasma information very useful for correct ICC setup!
ICC Development and Characterization

New status:
Process interactions with Insitu Chamber Clean (ICC)
Process interaction on Gate Poly Etch
[opticalemmision: Barc Endpoint]

Endpoint intensity and EP time are now very stable and indipendent to preceding etch process and its etch chemistry

With ICC after every wafer
Process interaction on Gate Poly Etch
[SEERS: plasma parameter RF current]

Barc  Poly-ME  -OE

BT  Dechuck

Remember:

Gate Poly Etch Process -> RF-Current with HERCULES

With ICC after every wafer
Process interaction on Emitter Etch

[optical emission: Poly Endpoint]

- Endpoint curve intensity are now very stable
- Endpoints can be detected safely

With ICC after every wafer.
Process interaction on Emitter Etch

[SEERS: plasma parameter RF current]

Remember:

Emitter Poly Etch without ICC

With ICC after every wafer
Fluorine based DT Barc Etch:
- Very stable Endpoint traces
- Stable Etch Rate

With ICC after every wafer
Process interaction on Emitter Etch

[SEERS: plasma parameter RF current]
**Process interaction on DT Barc Etch**

[process parameter: Barc Etch Rate]

<table>
<thead>
<tr>
<th>DT Barc Etch (C2F6) post prior Barc Etch (N2/O2)</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>2nd</td>
</tr>
<tr>
<td>2nd</td>
<td>3rd</td>
</tr>
<tr>
<td>post</td>
<td>post</td>
</tr>
<tr>
<td>prior Barc Etch</td>
<td>prior Barc Etch</td>
</tr>
</tbody>
</table>

**With ICC** after every wafer:
- BARC Etch Rates (both kind of Barc) increase
- Barc Etch Rate keep stable
- No more 1st Wafer effect
Very Deep Trench Etch @ AMAT
DPS DT chamber

Plasma Instabilities during DT Etch  (BICOM3X)
Very Deep Trench Etch @ AMAT DPS
DT chamber: problem verification
[SEERS: plasma parameter Collision rate]

Collision Rate and Electron Density during DT production cycle (between wet cleans)

- Wet cleans visible
- Conditioning
- Problems / issues visible
Very Deep Trench Etch @ AMAT DPS
DT chamber: problem verification

[SEERS: plasma parameter RF current]

- Drop of plasma RF current due to wrong test wafer which were run between production material
Very Deep Trench Etch @ AMAT DPS DT chamber: problem verification
[SEERS: plasma parameter RF current]

- **Reason for Drop:** Bias generator becomes too hot and shuts down
- **Root cause:** defect cooling fan
- **The process has not stopped,** because Bias-Power Settings are lower (12W) than Alarm limits
- **The process continuous with only Source Power**
Conclusion

The SEERS sensor ‘Hercules’ from Plasmetrex

• provides absolute physical plasma parameter in addition to the Endpoint data, which shows a small part of the optical plasma frequency spectrum

• afford comprehensive process investigations using detailed primary plasma information

• enables a more efficiently ICC setup

• provide information of correct ICC functionality quickly, easily and cost effective

• Allow detailed plasma monitoring and controlling
Thank You