Uniformity Characterization
of Technics-c

By Carolyn Kooi
Microlab Summer Intern 2007
Introduction

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My Project

- Uniformity is key
  - Higher yield
  - Keeps process costs down
- Non-uniformity can be destructive
  - Too much etching → damage to previous work on die
  - Too little etching → necessary process is not completed

Poor Mr. Non-Uniform Wafer wishing he were broken
My Project

Goal

- To characterize the current uniformity in Technics-c
- To pick a combination of upper and lower gas ring flows that maximizes uniformity
Process

- Grow silicon nitride ($\text{Si}_3\text{N}_4$) on silicon wafers
- Measure preliminary thickness of nitride with Nanospec
- Etch wafers in Technics-c
- Perform nine point measurement with Nanospec
- Calculate % non-uniformity
  - Defined by us as $\frac{\text{Max-Min}}{\text{Average}}$
Process

- **Tystar 9**
  - Deposition of nitride on silicon to create silicon nitride ($\text{Si}_3\text{N}_4$)
  - Low Pressure Chemical Vapor Deposition
    - $3\text{SiCl}_2\text{H}_2 + 4\text{NH}_3 \rightarrow \text{Si}_3\text{N}_4 + 6\text{HCl} + 6\text{H}_2$
Process

- Nanospec
  - Measures thickness of deposited nitride
  - Nine-point measurement
- Reflectometry
  - Sends down white light
  - Constant wavelength in air, when meets the nitride, there is thin film interference
  - Depending on substance on wafer, there is a constant rate of refraction
- Based on what is intensified and what is canceled out, it can detect the thickness of the deposited layer
Process

- Technics-c
  - Etches silicon nitride using SF$_6$ and He
- Method
  - Wafers placed on platen
  - Lid is closed and vacuum is turned on
  - Once pressure is ~40mT, SF$_6$ and He gas are let into the chamber
Process

- Gas feed
  - Back of upper electrode
  - Front of lower electrode
- Gas flows into chamber between platen and metal plate then enters through holes
Process

- Potential Problem
  - Gas distribution
    - Gas might not evenly disperse before entrance into chamber
    - Might cause non-uniform flow of gas in chamber
    - Center gas feed is optimal
Process

- Use 100W plasma
- The Process of Etching
  1) Dissociation
     \[ \text{SF}_6 + e^- \rightarrow \text{SF}_5 + F + e^- \]
  2) F and He interact with surface of wafers
     \[
     \begin{align*}
     F & \quad \text{He} \\
     \end{align*}
     \]
  3) Absorbed by nitride
     Bombards wafer
  4) Fluorine binds to Silicon to
     Knocks off Silicon Nitride
     form SiF$_3$ (Silicon tetraflouride)
  5) Volatile byproducts are removed with vacuum pump

Characterization of Technics-c

- Current Recipe for Nitride Etch
  - 100% gas on top
  - Flow rates
    - SF\textsubscript{6} 13.0 sccm
    - He 21.0 sccm
  - 100W

Problem

- When etched with current recipe wafers are not uniform
- % Non-uniformity
  - Front 23.6%
  - Back 27.6%

Differential Change in Thickness
(normalized to the mean)
2 Wafer Nitride Etch 100% Top

\[
\text{Differential Change in Thickness} = \frac{\text{Final}}{\text{Initial Mean}}
\]
Method

Maintain Orientation of Wafers (Flat towards outside)

Maintain all aspects of current recipe except for ratio of upper gas to lower gas flow

Current Recipe for Nitride Etch

Flow rates  Total flow rate 34 sccm

\[ \text{SF}_6 \] 13.0 sccm

\[ \text{He} \] 21.0 sccm

100W 100% gas on top (to be changed)

Alter ratio of upper gas to lower gas flow

Needle valves

Needle rests in a seat

Seat is maximum clearance

Needle adjusted into seat to decrease clearance between seat and needle

Needle adjusted out

Decreased flow rate

Increased flow rate

Method

- Two Needle Valves
  - With micrometers we can precisely set our openings
    - 20 tick marks
    - Highest tick mark defined as 100%
  - Varied ratio flow between upper and lower gas

![Diagram](image)
Method

- Constant pressure differential → constant total flow rate
- Constant total flow rate → gas is divided up by the ratio of upper to lower
  - In 100-33 division (3:1 ratio), flow rate in each tube is proportional to the ratio of the openings
Method- Non-Uniformity

<table>
<thead>
<tr>
<th>Lower Gas</th>
<th>0</th>
<th>25</th>
<th>33</th>
<th>50</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F 23.58% B 27.62%</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td>F 2.54% B 2.53%</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td>F 2.04% B 3.66%</td>
<td>F 1.61% B 3.82%</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>F 33.96% B 47.65%</td>
<td></td>
<td></td>
<td>F 5.26% B 9.38%</td>
<td></td>
</tr>
</tbody>
</table>
# Results

### Differential Change in Thickness

**Differential Change in Thickness (normalized to the mean) 2 Wafer Nitride Etch 100% Top**

<table>
<thead>
<tr>
<th>cm from center</th>
<th>1.1-1.15</th>
<th>1.05-1.1</th>
<th>1-1.05</th>
<th>0.95-1</th>
<th>0.9-0.95</th>
<th>0.85-0.9</th>
<th>0.8-0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td></td>
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</tr>
<tr>
<td>Right</td>
<td>1.07-1.09</td>
<td>1.05-1.07</td>
<td>1.03-1.05</td>
<td>1.01-1.03</td>
<td>0.99-1.01</td>
<td>0.97-0.99</td>
<td>0.95-0.97</td>
</tr>
</tbody>
</table>

### Differential Change in Thickness (normalized to the mean) 4 Wafer Nitride Etch 100-33

**RUN 1**

<table>
<thead>
<tr>
<th>cm from center</th>
<th>1.07-1.09</th>
<th>1.05-1.07</th>
<th>1.03-1.05</th>
<th>1.01-1.03</th>
<th>0.99-1.01</th>
<th>0.97-0.99</th>
<th>0.95-0.97</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td></td>
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<td>Back</td>
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<td>Right</td>
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</tr>
</tbody>
</table>

### Differential Change in Thickness (normalized to the mean) 4 Wafer Nitride Etch 100-33

**RUN 2**

<table>
<thead>
<tr>
<th>cm from center</th>
<th>1.07-1.09</th>
<th>1.05-1.07</th>
<th>1.03-1.05</th>
<th>1.01-1.03</th>
<th>0.99-1.01</th>
<th>0.97-0.99</th>
<th>0.95-0.97</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td></td>
<td></td>
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<td></td>
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<td>Right</td>
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</tr>
</tbody>
</table>

### %non-uniformity

<table>
<thead>
<tr>
<th></th>
<th>Run 1</th>
<th>Run 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>1.8%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Back</td>
<td>1.3%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Right</td>
<td>1.3%</td>
<td>2.9%</td>
</tr>
<tr>
<td>Left</td>
<td>1.2%</td>
<td>2.7%</td>
</tr>
</tbody>
</table>
Results

- Success in Nitride Etch
- Technics-c is also used for ashing and etching of Photoresist
- Tested 100 top (current recipe) and 100-33
  - \( \text{O}_2, 300\text{W}, 1\text{ minute} \)
  - Percentage of non-uniformity from 100-0 to 100-33 etch
    - F 8.4% \( \rightarrow \) 9.7%
    - B 20.5% \( \rightarrow \) 10.7%
    - R 15.7% \( \rightarrow \) 11.4%
    - L 15.7% \( \rightarrow \) 11.2%

\[
\text{Differential Change in Thickness} \quad = \quad \frac{\text{Final}}{\text{Initial}} \quad \frac{\text{Mean}}{\text{Mean}}
\]
Summary

Best recipe is a 100% top and 33% bottom

Decreased Percentage of Non-uniformity

Learned how to use and characterized Technics-c

Became a qualified user

What I learned

Reflectometry

Etching Process

<table>
<thead>
<tr>
<th></th>
<th>Run 1</th>
<th>Run 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.7%</td>
<td>1.4%</td>
</tr>
<tr>
<td></td>
<td>2.9%</td>
<td>2.0%</td>
</tr>
<tr>
<td></td>
<td>1.2%</td>
<td>1.8%</td>
</tr>
<tr>
<td></td>
<td>2.0%</td>
<td>2.7%</td>
</tr>
</tbody>
</table>
Acknowledgements

Thanks to everyone at the Microlab for patiently explaining things when I had questions, letting me in when I was locked out and making this a great summer.


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