Characterization of LPCVD TEOS Thin Film using Ellipsometer

by

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National Science and Technology Development Agency (NSTDA)
Basic Fabrication process consist of three major steps:

1. Deposition of thin films
2. Photolithography
3. Selective etching of the films.
THIN FILM DEPOSITION FOR BASIC ETCH PROCESS

[Diagram showing film deposition, PR ashing & clean, and subtractive processes]

THIN FILM DEPOSITION FOR FABRICATION PROCESS

[Diagram showing layers of materials like PE-Nitride, PE-Oxide, Al, TEOs, Nitride, TEOs, Poly]
Outline

- Thin film technology
- LPCVD system
- TEOS thin film deposition
- Characteristics of TEOS thin films
- Conclusion
Outline

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Thin film technology

Deposition technologies can be divided into two groups:

1. Physical Vapor Deposition (PVD) process
2. Chemical Vapor Deposition (CVD) process
Type of Deposition Methods

Physical Vapor Deposition: PVD
- Evaporation
- E Beam evaporation
- Sputtering

Chemical Vapor Deposition: CVD
- Plasma Enhanced CVD (PECVD)
- Atmospheric Pressure CVD (APCVD)
- Low Pressure CVD (LPCVD)
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Low Pressure CVD (LPCVD)

Advantage
- Moderate deposition rates
- Very high throughput
- Minimal contamination

Disadvantage
- Film contamination (reaction products and carrier gases)
LPCVD horizontal hot-wall furnace system
SVG LPCVD furnace THERMCO TMX2603 at Thai Microelectronics Center (TMEC)
Structure of LPCVD TEOS furnace

Computer Control  TEOS liquid source

Quartz Boat  Gas cabinet & Vacuum System
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Step in film growth

- Gases are introduced into a reaction chamber
- Gas species move to the substrate
- Reactants are adsorbed on the substrate
- Film-forming chemical reactions
- Desorption and removal of gaseous by-products
Oxide (SiO$_2$) Films Deposition

- Silane & Oxygen (300-500 C)
  \[ \text{SiH}_4 + \text{O}_2 \rightarrow \text{SiO}_2 + 2\text{H}_2 \]
  \[ 450 \text{ C} \]

- Tetraethylorthosilicate: TEOS (500-800 C)
  \[ \text{Si(OC}_2\text{H}_5)_4 \rightarrow \text{SiO}_2 + \text{by-products} \]
  \[ 700 \text{ C} \]

- Dichlorosilane & Nitrous (\sim 900 C)
  \[ \text{SiCl}_2\text{H}_2 + 2\text{N}_2\text{O} \rightarrow \text{SiO}_2 + 2\text{N}_2 + 2\text{HCl} \]
  \[ 900 \text{ C} \]
TEOS Films by LPCVD

Advantage
- Isolation layer
- Step coverage
- Hard mask
- Moderate deposition rate

Disadvantage
- Bad thickness uniformity (~3%)
Uniformity (%) = \left[ \frac{\text{Standard deviation}}{\text{Thickness average}} \right] \times 100
### Process A: Different Operate Pressure

<table>
<thead>
<tr>
<th>Technique</th>
<th>LPCVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>705 °C</td>
</tr>
<tr>
<td>Gas flow TEOS</td>
<td>80 SCCM</td>
</tr>
<tr>
<td>Operate Pressure</td>
<td>150, 200, 250, 300 mtorr</td>
</tr>
<tr>
<td>Deposit Time</td>
<td>20 minute</td>
</tr>
<tr>
<td>Wafer spacing</td>
<td>Normal</td>
</tr>
</tbody>
</table>

### Process B: Different Temperature

<table>
<thead>
<tr>
<th>Technique</th>
<th>LPCVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>680, 690, 700, 705, 710 °C</td>
</tr>
<tr>
<td>Gas flow TEOS</td>
<td>80 SCCM</td>
</tr>
<tr>
<td>Operate Pressure</td>
<td>200 mtorr</td>
</tr>
<tr>
<td>Deposit Time</td>
<td>20 minute</td>
</tr>
<tr>
<td>Wafer spacing</td>
<td>Normal</td>
</tr>
</tbody>
</table>
Process A.

**Dep rate VS. Operate pressure**
- Deposition rate (nm/min) vs. Pressure (mTorr)
- Graph shows a positive correlation between deposition rate and pressure.

**Uniformity VS. Operate pressure**
- Uniformity (%) vs. Pressure (mTorr)
- Graph indicates a slight increase in uniformity with pressure.

Process B.

**Dep rate VS. Temperature**
- Deposition rate (nm/min) vs. Temperature (degree C)
- Graph shows a positive correlation between deposition rate and temperature.

**Uniformity VS. Temperature**
- Uniformity (%) vs. Temperature (degree C)
- Graph indicates a slight increase in uniformity with temperature.
### Process C: Wafer spacing

<table>
<thead>
<tr>
<th>Technique</th>
<th>LPCVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>705 °C</td>
</tr>
<tr>
<td>Gas flow TEOS</td>
<td>80 SCCM</td>
</tr>
<tr>
<td>Operate Pressure</td>
<td>175, 200, 225 mtorr</td>
</tr>
<tr>
<td>Deposit Time</td>
<td>20 minute</td>
</tr>
<tr>
<td>Wafer spacing</td>
<td>Adjustment</td>
</tr>
</tbody>
</table>

### Process D: Different Deposition Time

<table>
<thead>
<tr>
<th>Technique</th>
<th>LPCVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>705 °C</td>
</tr>
<tr>
<td>Gas flow TEOS</td>
<td>80 SCCM</td>
</tr>
<tr>
<td>Operate Pressure</td>
<td>200 mtorr</td>
</tr>
<tr>
<td>Deposit Time</td>
<td>30, 60, 90 minute</td>
</tr>
<tr>
<td>Wafer spacing</td>
<td>Adjustment</td>
</tr>
</tbody>
</table>
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ELLIPSOMETER

Thin Film Measurement at Thai Microelectronics Center (TMEC)
# Properties of Silicon Dioxide Films

<table>
<thead>
<tr>
<th>Property</th>
<th>Thermally at 1000 C</th>
<th>SiH4+O2 at 450 C</th>
<th>TEOS at 700 C</th>
<th>SiCl2H2+N2O at 900 C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>SiO₂</td>
<td>SiO₂(H)</td>
<td>SiO₂</td>
<td>SiO₂(Cl)</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>2.2</td>
<td>2.1</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Refractive index</td>
<td>1.46</td>
<td>1.44</td>
<td>1.46</td>
<td>1.46</td>
</tr>
<tr>
<td>Strength (10⁶V/cm)</td>
<td>&gt;10</td>
<td>8</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Etch rate (nm/min) (100:1 H2O:HF)</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Etch rate (nm/min) (buffered HF)</td>
<td>44</td>
<td>120</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Step coverage</td>
<td>-</td>
<td>non conformal</td>
<td>conformal</td>
<td>conformal</td>
</tr>
</tbody>
</table>

*Fundamentals of Semiconductor Fabrication (page 158)*
## Properties of TEOS Films by LPCVD

<table>
<thead>
<tr>
<th>Property</th>
<th>TEOS at 705 C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>SiO₂</td>
</tr>
<tr>
<td>Refractive index (n)</td>
<td>~1.45</td>
</tr>
<tr>
<td>Absorption coefficient (k)</td>
<td>0.0000</td>
</tr>
<tr>
<td>Wafer uniformity (%)</td>
<td>~1.0</td>
</tr>
<tr>
<td>6 inch wafer</td>
<td></td>
</tr>
<tr>
<td>Deposition rate (nm/min)</td>
<td>9.2</td>
</tr>
<tr>
<td>Etch rate (nm/min)</td>
<td>66</td>
</tr>
<tr>
<td>HF3%</td>
<td></td>
</tr>
<tr>
<td>Step coverage</td>
<td>Conformal</td>
</tr>
</tbody>
</table>
TEOS Thin Film by LPCVD for Application
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Conclusion

The silicon dioxide (TEOS) films have wafer uniformity about 1.0 \% refractive index about 1.45 absorption coefficient of 0.0 deposition rate of 9.2 nm/min Etch rate (HF3\%) of 66 nm/min
Acknowledgements

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Thank you for your attention