Modeling and Fabrication of Piezoelectric RF MEMS Resonators

Andrew Potter
SUNFEST 2007
Final Presentation
Project Goals

1. Optimize and Characterize ICP Etching
   a. Silicon Oxide Etching
   b. Aluminum Nitride Etching

2. Simulate the Effects of Non-Ideal Etch Profiles
ICP Characterization
Fabrication Steps

- Oxide
- Photo-Resist
- AlN
- Silicon Substrate
- Platinum
ICP Characterization

- Anisotropic
- Isotropic

Side-Wall Sloping

Etch mask

Masking Layer

Substrate

Layer to Be Etched

θ
Oxide Etching

Etch Rate vs. RIE Power (SpOx)
50sccm CF4, 100mT, 500W ICP

Best Selectivity Recipe:
P: 100mT  Flow: 50sccm
RIE: 50W   ICP: 500W
Selectivity: 1:3 (Sputtered)
            1:4 (PECVD)
Oxide Rate: 50nm/min (SpOx)
            35nm/min (PECVD)
Etchant: CF4
Masking Layer: Photo-Resist
**AlN Etching**

**Recipe Characterization:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>100mT</td>
</tr>
<tr>
<td>BCl₃</td>
<td>25sccm</td>
</tr>
<tr>
<td>Cl₂</td>
<td>25sccm</td>
</tr>
<tr>
<td>Ar</td>
<td>10sccm</td>
</tr>
<tr>
<td>RIE</td>
<td>50W</td>
</tr>
<tr>
<td>ICP</td>
<td>500W</td>
</tr>
<tr>
<td>Selectivity</td>
<td>4:1 (SpOx)</td>
</tr>
<tr>
<td></td>
<td>6:1 (PECVD Ox)</td>
</tr>
<tr>
<td>AlN Rate</td>
<td>~200nm/min</td>
</tr>
<tr>
<td>Etchant</td>
<td>BCl₃, Cl₂ and Ar</td>
</tr>
<tr>
<td>Masking Layer</td>
<td>Oxide</td>
</tr>
</tbody>
</table>

**AlN Etch Profile (SEM Micrograph)**
Modeling and Simulations
Figures of Merit

Typical Admittance Plot

Admittance

\[ Y = 20 \log_{10} \left( \frac{I}{V} \right) \]

Quality Factor

\[ Q = \frac{f_{\text{res}}}{f_{3\text{dB}_2} - f_{3\text{dB}_1}} \]

Efficiency

\[ k_t^2 = \frac{\pi^2}{4} \left( \frac{f_{\text{anti-res}}}{f_{\text{anti-res}} - f_{\text{res}}} \right) \]
Simulation Methods

**COMSOL Multiphysics (Piezo Plane-Stress)**

- Loss Factor Damping ($\eta=1/1000$)
- Applied Voltage Amplitude: 1Vpp
- Platinum Thickness: 200nm
  (80% Coverage on Multi-Fingered Devices)
Mode Shapes

1-Fingered

3-Fingered

5-Fingered
Frequency Shift vs. Sidewall Angle

**One Finger**

- Resonance
- Anti-Resonance

**Three Fingers**

- Resonance
- Anti-Resonance

**5-Fingered**

- Resonance
- Anti-Resonance

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kt^2 vs. Sidewall Angle

One Finger

Sidewall Slope (degrees)

kt^2 (percent)

Three Fingers

Sidewall Angle (degrees)

kt^2 (percent)

5 Fingers

Sidewall Angle (degrees)

kt^2 (%)
What’s Left

1. Optimize ICP Etching
   a. Oxide Etching – Want Higher Etch Rates Without Sacrificing Selectivity
   b. Aluminum Nitride – Try to Optimize Etching Profile
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