SPTS APS PM Overview
Prepared for Customers

August 2013
Details on APS applications
- Oxide & nitride
- Deep oxide
- Glasses
- Sapphire
- SiC/GaN
- PZT/Pt
- Endpoint Capability

Summary
# Strongly Bonded Materials & Markets

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- Requirement to etch strongly bonded materials across multiple end markets
Magnetic confinement reduces electron & ion losses to walls/lid

Heated chamber reduces radical losses

Small, multi-turn planar coil & ceramic

Inductively coupled plasma

Higher ion and radical densities

Best suited to strongly ion driven chemical etching

~100x AOE/APS modules installed
Waveguide Core Etching

- Typical etch rate 0.3-0.5 µm/min depending on oxide type & doping
Waveguide Termination Etch

- Cladding layer etch

- 200 mm quartz wafer
- Poly Si mask
- Etch depth ~40µm
- Etch rate 6000 Å/min
- Profile 90º
- Selectivity to mask >30:1
- Uniformity ±4%
Deep Oxide Etching Challenges

- Range in etch depths depends on end market
  - ~6µm for waveguide cores
  - 10’s of µm for waveguide termination (cladding etch)
  - 100’s of µm for lenses & through wafer applications

- 3 types of mask used
  - PR – lowest selectivity, limited on depth
  - Si (amorphous or poly) – medium selectivity, deeper etches
  - Metals (Al, Cr, Ni) – highest selectivity, for deep etching and HAR

- Glass etching behaviour depends on glass type
- Pure quartz & fused silica etch like thermal oxide
  - Smooth etching, lower bias powers
- Pyrex contains impurities – B, Na, Al, Fe, Ca, Mg ..
  - Rougher surfaces, higher bias powers

- SPTS has large install base
  - >40x Etch PMs for waveguide & related applications
Silicon Oxide Etch

- Etch depth 0.5 µm
- Etch rate 0.3 µm/min
- Uniformity <±4%
- $S_{PR} \sim 4:1$
- $S_{Si} \sim 14:1$
- Profile ~80-88°
- Feature dependant
Oxide Contact Etching

- ~0.7µm diameter x 0.87µm deep contact etch

- C₄F₈/He/H₂ chemistry
- Etch rate 0.33µm/min
- S_{PR} ~3:1
- S_{Poly} >10:1
- S_{TiSix} >8:1
- Profile ~90°

1.6µm PR
TEOS/BPSG stack
Poly & TiSix stop layers
<1% open area
150mm Si wafer
Tapered Oxide Contact Etching

- Etch rate 0.65µm/min
- Uniformity ±3-4%
- Profile ~69°
- $S_{PR} \sim 1.5:1$
- Si loss <0.5µm
Silicon Oxide Etch

- Etch depth 4.3 µm
- Partial etch
- Etch rate 0.53 µm/min
- Uniformity <±3%
- \( S_{PR} \approx 2.7:1 \)
- Profile ~80°
- Mask dependant
Silicon Oxide Etch

- Etch depth 7µm
- Etch rate 0.54 µm/min
- Uniformity ±1%

Before oxide etch

- 1 µm Poly Si mask

After oxide etch
Sub-Micron HAR Oxide Etching

Metal mask 0.5µm features 3.5µm deep ~7:1 AR

Metal mask 0.6µm features 12.0µm deep ~20:1

Si mask 0.24µm features 0.5µm deep

- Etch rate 0.5µm/min
- Selectivity >50:1
- Profile 89-90°

- Etch rate 0.28µm/min
- Selectivity >50:1
- Profile 89-90°

- Etch rate 0.3µm/min
- Selectivity >5:1
- Profile 86°
Silicon Nitride Etch

- Etch depth 0.2 µm
  - Partial etch
- Etch rate 0.35 µm/min
- Uniformity <±3%
- S_{PR} ~2.9:1
- Profile ~84°
  - Mask dependant
Silicon Nitride Etch

- PR mask
- Etch depth ~2.5 µm
- Etch rate ~0.5 µm/min
- \( S_{PR} > 3:1 \)
- Uniformity \(<±3\%\)
- Profile ~89°
Sub-Micron Silicon Nitride Etch

- 500nm features
- PR mask
- Etch rate ~0.42 µm/min
- $S_{PR}$ 1.3:1
- Profile angle 90.5°
Quartz Glass Etching

- Depth, etch rate & selectivity depend on mask type

**PR mask**
- Etch depth ~8µm
- Etch rate ~0.29µm/min
- Profile ~89°
- $S_{PR} \sim 5:1$

**Si mask**
- Etch depth ~20µm
- Etch rate ~0.49µm/min
- Profile ~89.8°
- $S_{Si} \sim 18:1$

**Al mask**
- Etch depth ~90µm
- Etch rate ~0.60µm/min
- Profile ~90.5°
- $S_{Al} \sim 40:1$

Quartz tuning forks
- Ti/Ni/Au mask
- Etch depth ~80µm
- Etch rate ~0.32µm/min
- Profile ~91.5°
Fused Silica Glass Etching

20µm trenches
   Al mask
   Etch depth ~37µm
   Etch rate ~0.58µm/min
   Profile ~85°
   $S_{Al} ~27:1$

40µm trenches
   Ni mask
   Etch depth ~100µm
   Etch rate ~0.64µm/min
   Profile ~88.8°
   $S_{Ni} ~15:1$
Pyrex Glass Etching

- Depth, etch rate & selectivity depend on mask type

- 4 µm SU8 PR mask
  Etch depth ~7 µm
  Etch rate ~0.34 µm/min
  Profile ~81°
  \(S_{SU8PR} \approx 4.7:1\)

- 4 µm Al mask
  Etch depth ~20 µm
  Etch rate ~0.65 µm/min
  Profile ~73.0°
  \(S_{Al} \approx 11:1\)

- 1.5 µm Cr mask
  Etch depth ~6 µm
  Etch rate ~0.80 µm/min
  Profile ~80.0°
  \(S_{Cr} \approx 19:1\)

- 4 µm Cr mask
  Etch depth ~20 µm
  Etch rate ~1.4 µm/min
  Profile ~83.0°
  \(S_{Cr} \approx 20:1\)
Pre-patterning Sapphire for LEDs

- Pre-forming features in sapphire
  - Improves GaN dislocations
  - Increases light efficiency by reflection
- Wet etching is crystallographic
  - Doesn’t offer shape flexibility
- Dry etching requires mechanical clamping (combo with ESC)
  - Minimal wafer overlay for best uniformity
- Etch rate ~150 nm/min
- Profile ~55°
- \( S_{PR} \sim 0.3-0.7:1 \) (controls shape)
  - Peaked or flat topped cones
- Smooth sidewalls
SiC Via Etching for GaN Power

- Compound Semi Fab activity
  - High power from wide band-gap materials
- A challenging application
- Issues wrt clamping & cleanliness
  - Mechanical clamping preferred
  - Low volatility of etch by-products
  - Bonded wafer temperature
- Industry leading capability
  - Proprietary descum minimises pillar defects
  - Etch rate ~1.3µm/min
  - Selectivity to Ni mask ~35:1
  - Profile ≤90°
  - Wafer temp <116°C

80 x 100µm Via
GaN Etch at Via Base

- 100µm deep SiC via etched to GaN stop layer
  - GaN loss <0.35µm

- Base of SiC via after GaN etching
  - GaN etch rate ~0.49µm/min
  - Profile <90°
  - Metal loss <0.6µm
PZT Etch – Single Step Process

- Etch depth 0.5µm
- Etch rate 0.18µm/min
- $S_{PR} \sim 1.2:1$
- $S_{Pt} \sim 1:1$
- Profile $\sim 70^\circ$
High selectivity over-etch

- Etch rate 27nm/min
- \( S_{PR} \approx 0.24:1 \)
- \( S_{Pt} \approx 12:1 \)
- Profile \( \approx 70^\circ \)
Deep PZT Etch – PR Mask

- Etch depth ~2µm
- Etch rate 0.2µm/min
- $S_{PR} \sim 2:1$
- $S_{Pt} \sim 4:1$
- Profile ~72°
Deep PZT Etch – Ni Mask

- Etch depth up to 15µm
- Etch rate 0.2µm/min
- $S_{\text{Ni}} \sim 8:1$
- Profile $\sim 72^\circ$
Pt Etch

- Etch rate 0.18µm/min
- $S_{PR} \sim 1.3:1$
- $S_{Pt} \sim 1.6:1$
- Profile $\sim 70^\circ$
Endpoint Capabilities for APS

- Verity OES hardware utilized for endpoint monitoring and control (mounted to chamber viewport):
  - On-wafer etching, on-chamber cleaning, etc. (200-800nm)
  - Integrated to software, recipe control, can be field upgraded

- Applications with endpoint:
  - SiO2, SiN, SiC, GaN (for various exposed areas/patterns)
  - Select regions of interest, control with overetch features

Oxide etching, 0.4% exposed area pattern to Si etch stop (monitoring 440nm)

SiC etching, main etch process, stopping before GaN exposed (monitoring 440nm)
Summary

- Strongly bonded materials are used extensively within SPTS’s target markets
  - MEMS, waveguides, compound, power & advanced packaging
- APS is well suited to etching strongly bonded films
  - High ion & radical densities
- APS applications capability includes:
  - Dielectric etching
  - Deep oxide etching for waveguides & related
  - Glass etching
  - Sapphire etching
  - SiC/GaN
  - PZT/Pt
- APS endpoint capabilities for various applications