Tapered Trenches for Microelectromechanical Systems

AKT/Applied Materials
MEMS Product Group

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Introduction

What is AKT Inc. and what do we have to do with MEMS?

* Fully owned subsidiary of Applied Materials
* Opto-MEMS group goals:
  - To modify Applied Materials’ existing product line to serve the MEMS and optical markets
  - To create new products that specifically serve the MEMS community
AKT Inc. is an Applied Materials subsidiary, #1 supplier of CVD systems to manufacturers of flat panel displays.
Manufacturing Platforms

Applied Materials - Silicon Sector

Opto / MEMS

Centura-II

OM-1

**Opto / MEMS Requirements:**
- Lower Wafer Volumes
- Lower Costs
- Same Chamber IC Requirements

**Opto / MEMS Customer Needs:**
- Volume Manufacturing Expandability
- Support Infrastructure
- Technology Leader
- Market Leader
Opto/MEMS OM-1 Platform under construction

Plasma Source

Throttle Valve

Gate Valve

Turbo Pump

Source Generator

Bias Generator

Turbo Controller

Power Supply

VME Controller

System Monitor
AKT Opto/MEMS Process Chambers

Silicon Etch

PECVD

Dielectric Etch
The DPS Deep Trench System

* Decoupled Plasma Source Reactive Ion Etch
* 2 base chemistries
  - $\text{C}_4\text{F}_8/\text{SF}_6$ cyclic etch
  - $\text{SF}_6/\text{HBr}/\text{O}_2$ single step etch
* Process kits for 4”, 6”, and 8” as well as arbitrary wafer and die sizes and through wafer etches
* Single chamber or multi chamber
Applications Requiring Tapered Trenches

* Optical Fiber Alignment
  - In plane
  - Perpendicular
* Microfluidics
  - Plastic micromolding
* Metal Electroforming
KOH Etching

* Benefits
  - Large angle (54.7 degrees)

* Problems
  - Wet etch
  - Wafer orientation dependent
  - Fixed angle
**SF$_6$/C$_4$F$_8$ Etch, High Deposition**

Fig. 1: (a) Bare wafer is patterned using a photoresist mask (b) Partially anisotropic SF$_6$ etch for initial trench formation (c) Thick layer of polymer is deposited on trench bottom and sidewalls (d) At the start of the etch cycle, the bottom of the trench is cleared of photoresist before the sides. The etch selectivity between the polymer on the bottom and the polymer on the sides is large due to the bias, causing the SF$_6$ to be anisotropic. (e) The next etch cycle follows the same steps, but the trench width is smaller due to the smaller effective mask feature size.
SF₆/C₄F₈ Etch, High Deposition

* Benefits
  - Fine control of etch angle
  - Dry etch
  - Orientation independent
  - Manufacturability

* Problems
  - Max angle 87.5°
  - Scalloping
  - Grass in high open area regions
SF$_6$/C$_4$F$_8$ Etch, High Deposition
Etch Profiles

Increase power and deposition

Increase power and deposition, decrease etch amount
**SF$_6$/$C_4F_8$ Etch, Undercut Method**

Fig. 3:  
(a) The bottom critical dimension of the trench is specified using resist  
(b) An initial isotropic etch is performed  
(c) A conformal polymer layer is deposited over entire trench  
(d) During the first part of the next etch step, only the bottom of the trench is cleared of polymer due to the mild applied bias  
(e) Due to the high pressure, high energy ions are able to clear the sidewalls of polymer as well. The etch then continues in all directions equally  
(f) After numerous steps, a positive tapered profile becomes apparent.
SF\textsubscript{6}/C\textsubscript{4}F\textsubscript{8} Etch, Undercut Method

* Benefits
  - Fine control of etch angle
  - Dry etch
  - Orientation independent
  - Manufacturability
  - Angle variable up to $88^\circ$
  - Minimal sidewall roughness
  - High etch rates (>4 \textmu m/min, often >7 \textmu m/min)

* Problems
  - Rounding of corner at top of trench difficult to control
SF$_6$/C$_4$F$_8$ Etch, Undercut Method
Pressure Dependence

Low Pressure
Ethch Rate: 4.2 \( \mu \text{m/min} \)
Profile: 88°

Medium Pressure
Etch Rate: 7 \( \mu \text{m/min} \)
Profile: 75°

High Pressure
Etch Rate: 7.4 \( \mu \text{m/min} \)
Profile: 70°
Trends With Pressure
Trench Filled with Polymer

Tapered Trench Filled with Polymer
Smoothing Process

Using a patented Applied Materials process to reduce sidewall scallops.
Conclusion

* Trenches with taper angles from 90° to 65° have been achieved (of course reentrant trenches are possible as well)
* Higher etch pressures yield a larger taper when using the undercut method
* A smoothing process has been demonstrated
Contact Information

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