Tapered Trenches for Microelectromechanical Systems

AKT/Applied Materials MEMS Product Group

June 13, 2002

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Preview

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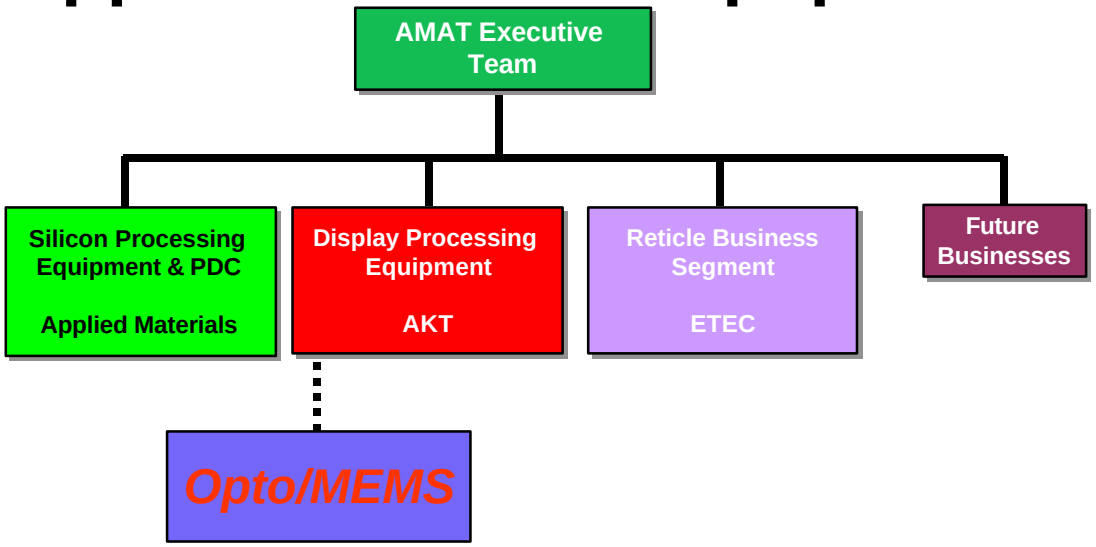
- Why tapered trenches?
- Other approaches
- Our method
- Sidewall smoothing
- Conclusion

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

Applied Materials Equipment Structure



AKT Infrastructure

AKT Purchasing

AKT Lab space

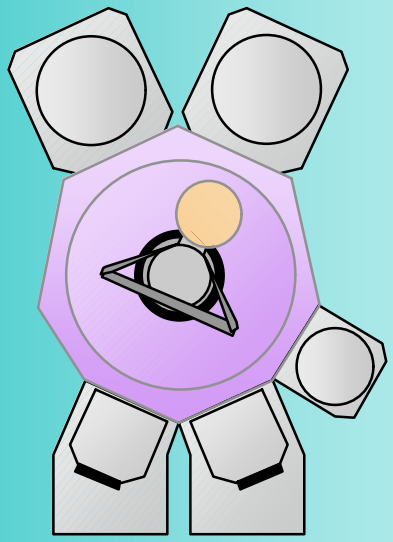
Separate from AMAT Si-IC

Full access to AMAT resources

AKT Inc. is an Applied Materials subsidiary, #1 supplier of CVD systems to manufacturers of flat panel displays.

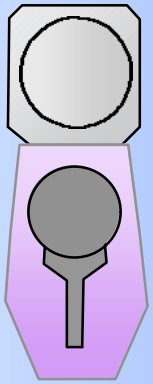
Manufacturing Platforms

Applied Materials - Silicon Sector



Centura-II

Opto / MEMS



OM-1

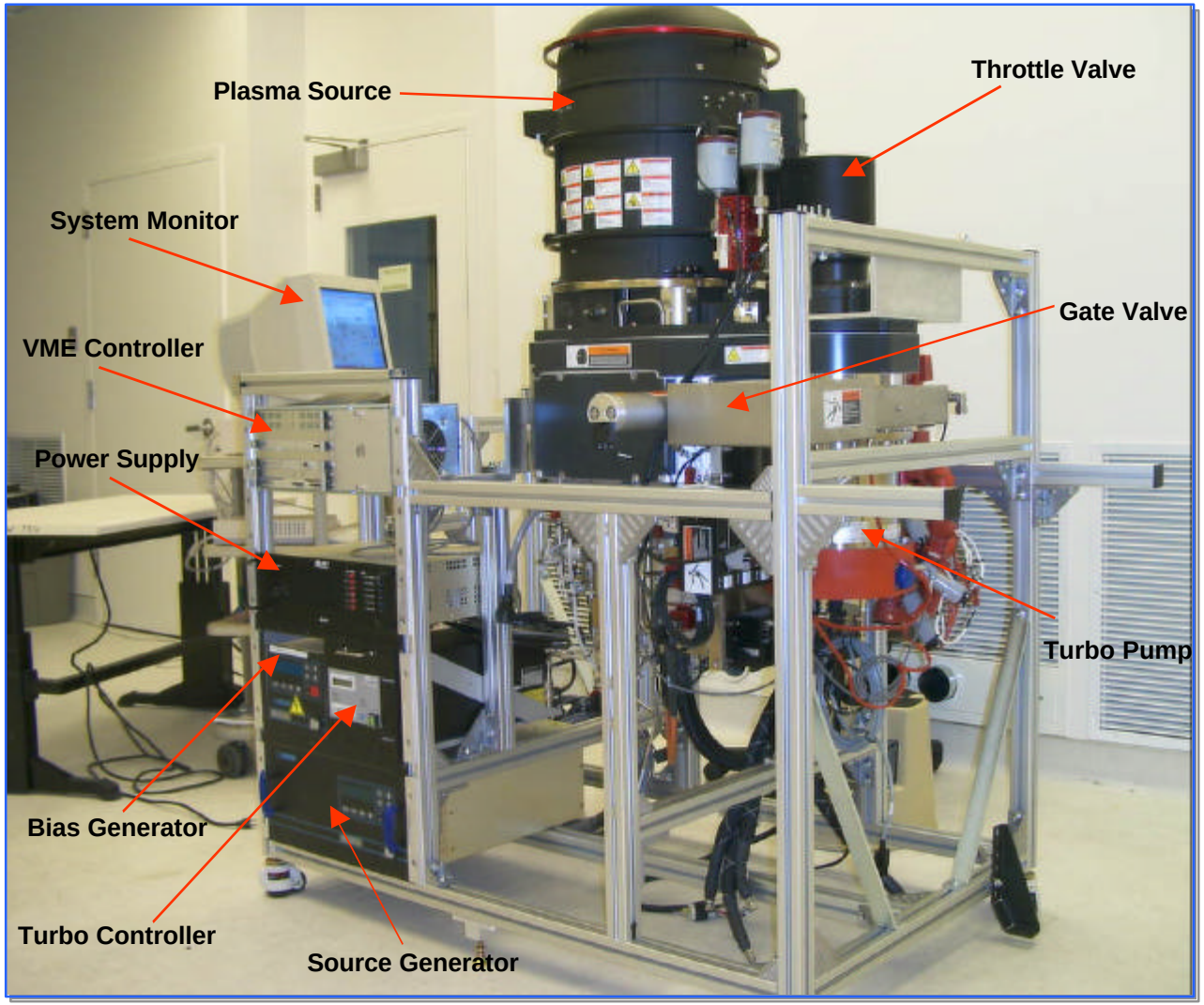
Opto / MEMS Requirements:

- Lower Wafer Volumes
- Lower Costs
- Same Chamber IC Requirements

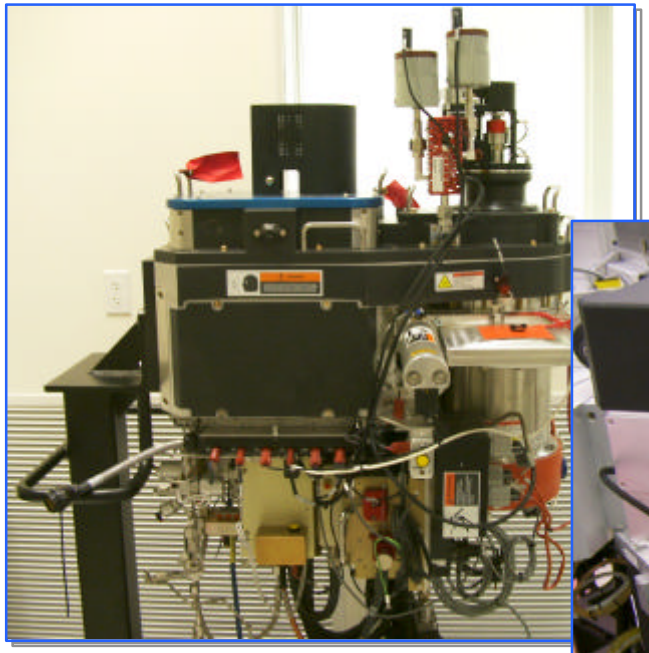
Opto / MEMS Customer Needs:

- Volume Manufacturing Expandability
- Support Infrastructure
- Technology Leader
- Market Leader

Opto/MEMS OM-1 Platform under construction



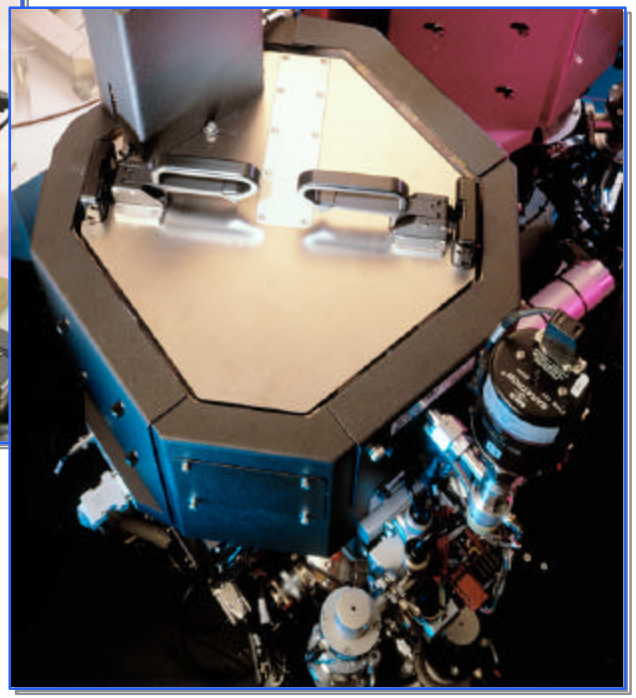
AKT Opto/MEMS Process Chambers



Silicon Etch

PECVD

Dielectric Etch



The DPS Deep Trench System

- Decoupled Plasma Source Reactive Ion Etch
- 2 base chemistries
  - C_4F_8/SF_6 cyclic etch
  - $SF_6/HBr/O_2$ 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_4F_8 Etch, High Deposition

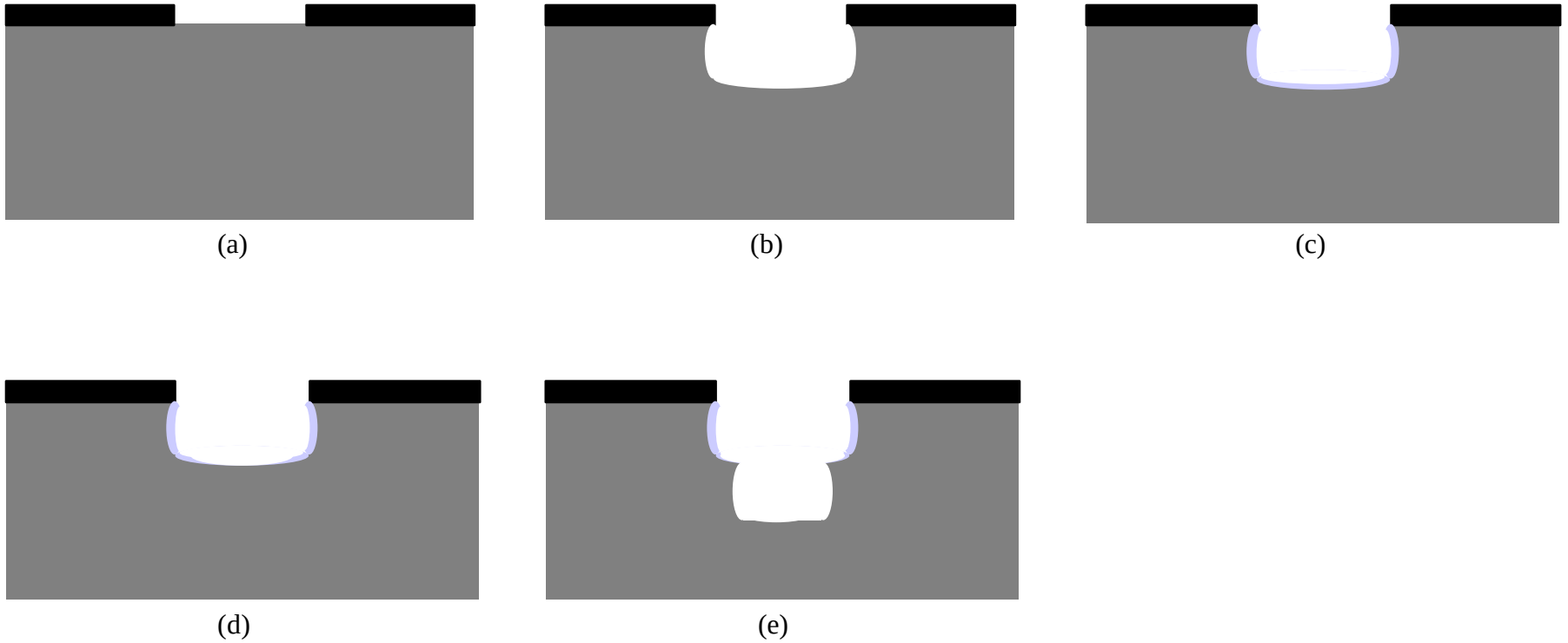


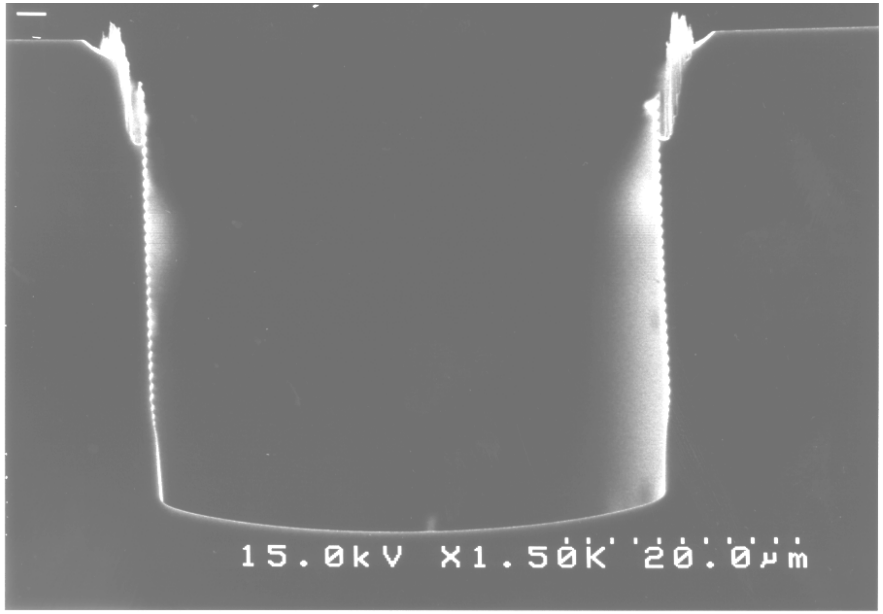
Fig. 1: (a) Bare wafer is patterned using a photoresist mask (b) Partially anisotropic SF_6 etch for initial trench formation (c) Thick layer of polymer is deposited on trench bottom and sidewalls (d) At the start of the etch cycle, the bottom of the trench is cleared of photorestist before the sides. 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.

SF_6/C_4F_8 Etch, High Deposition

* Benefits
  - Fine control of etch angle
  - Dry etch
  - Orientation independent
  - Manufacturability
* Problems
  - Max angle 87.5º
  - Scalloping
  - Grass in high open area regions

SF_6/C_4F_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

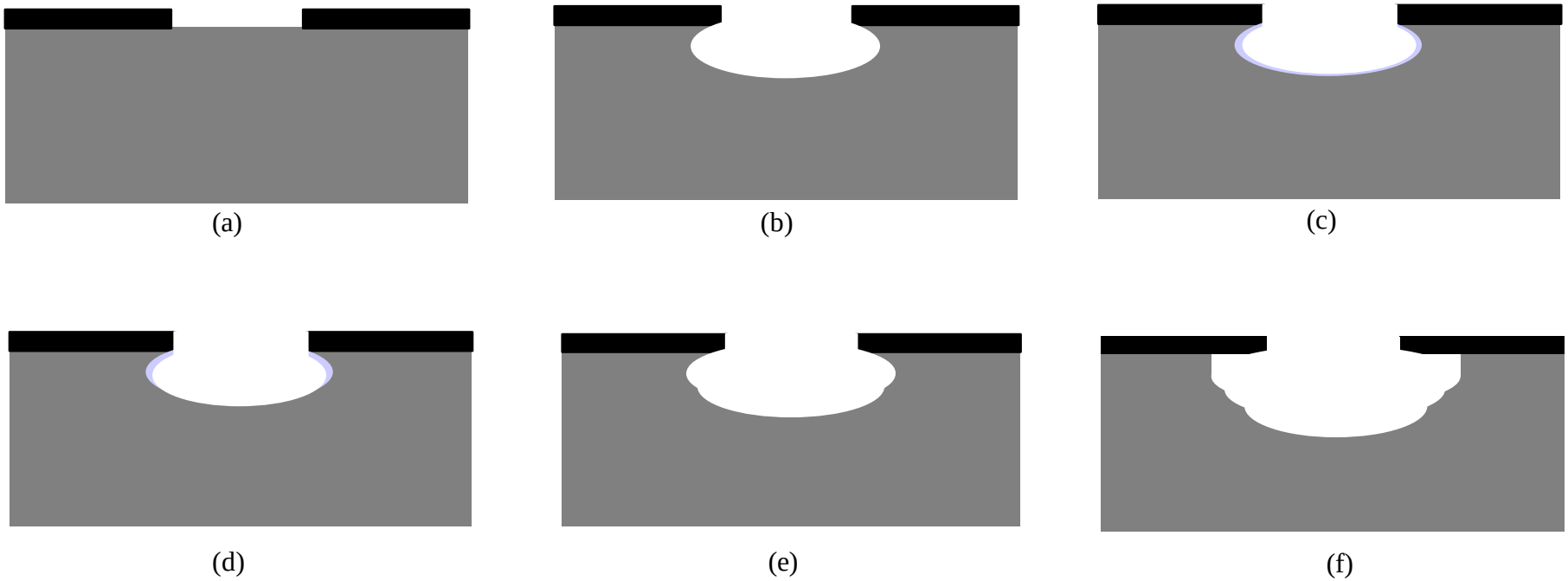
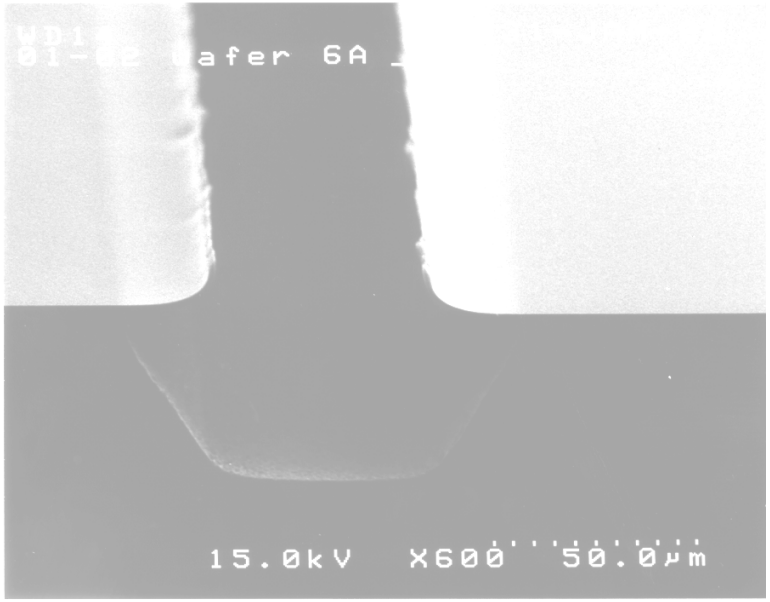


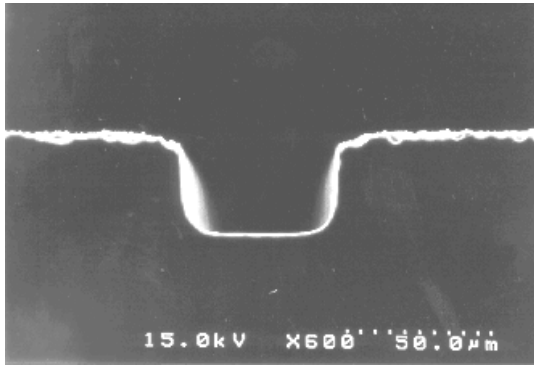
Fig. 3: (a) The bottom critical dimension of the trench is specified using resist (b) An initial isotropic etch is performed (c) A conformal polymer layer is deposited over entire trench (d) During the first part of the next etch step, only the bottom of the trench is cleared of polymer due to the mild 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_6/C_4F_8 Etch, Undercut Method



* Benefits
  - Fine control of etch angle
  - Dry etch
  - Orientation independent
  - Manufacturability
  - Angle variable up to 88º
  - Minimal sidewall roughness
  - High etch rates (>4ìm/min, often >7ìm/min)
* Problems
  - Rounding of corner at top of trench difficult to control

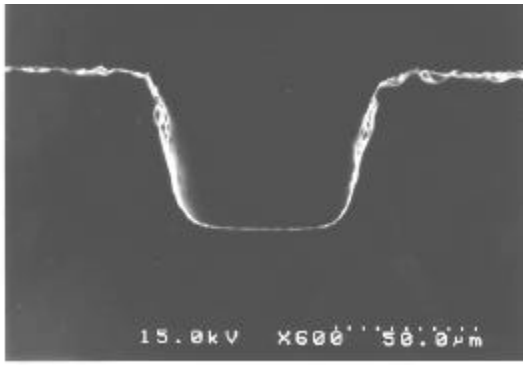
SF_6/C_4F_8 Etch, Undercut Method Pressure Dependence



Low Pressure

Etch Rate: 4.2 ìm/min

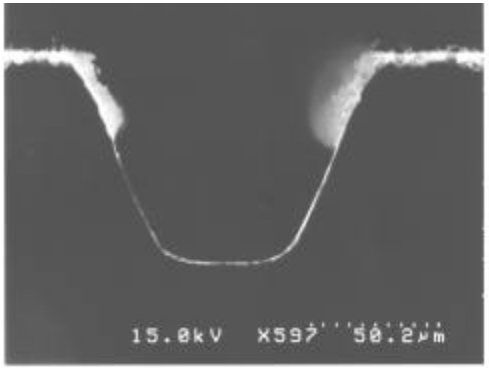
Profile: 88°



Medium Pressure

Etch Rate: 7 ìm/min

Profile: 75°



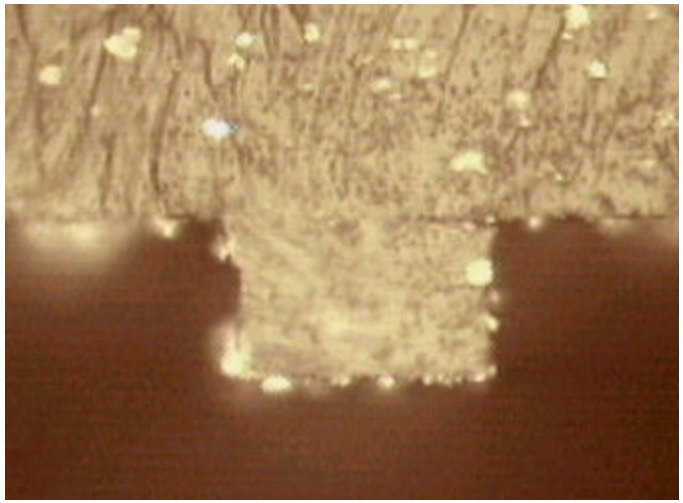
High Pressure

Etch Rate: 7.4 ìm/min

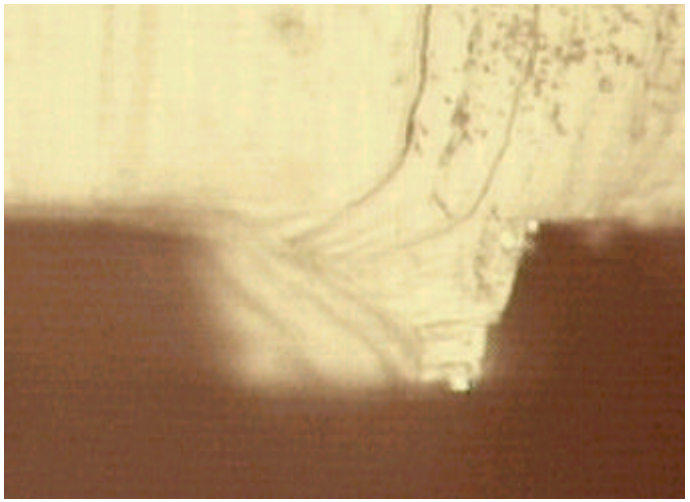
Profile: 70°

Trends With Pressure

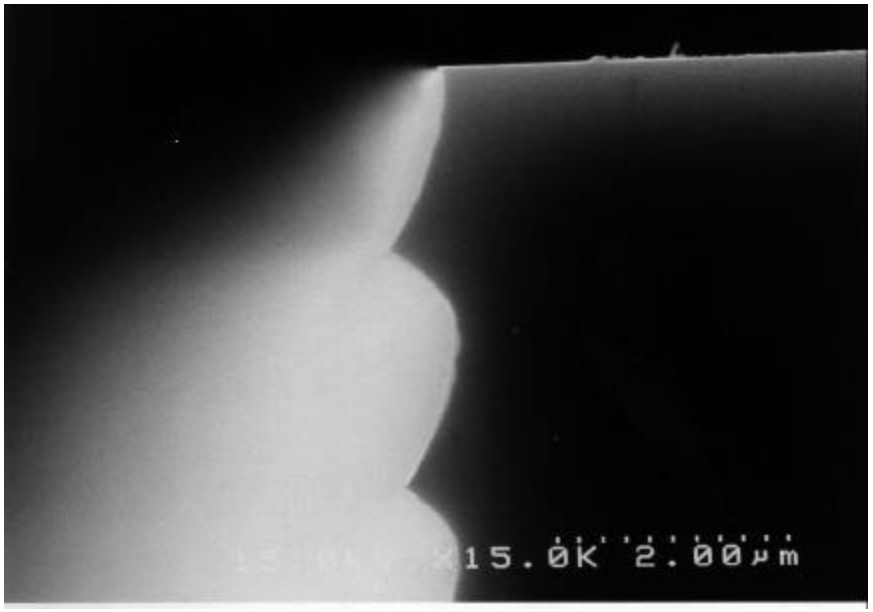
Trench Filled with Polymer

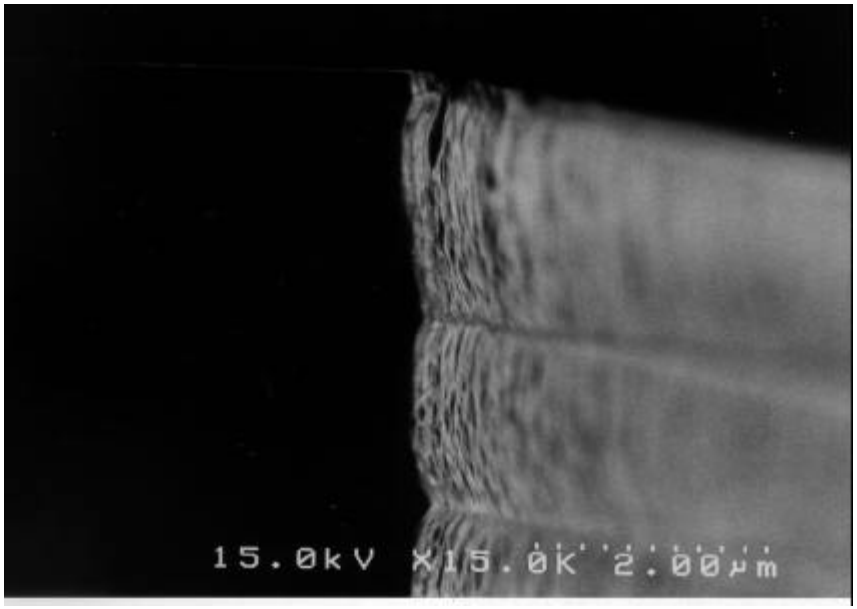


Tapered Trench Filled with Polymer



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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