Highly Selective MEMS Release

XACTIX, Inc

Overview

- Corporate Overview
- Xenon Difluoride Etch Process
- MEMS Application Examples
- Other Application Examples
- XACTIX Equipment

XACTIX Overview

XACTIX

- The source for xenon difluoride etching technology
- Ten years working with premier commercial customers and MEMS R&D programs.
- Over 100 Machines installed or in Progress
- US, Japan, Taiwan, Korea, China, Europe, Canada, Malaysia
- Full time process and equipment R&D effort leading to a growing IP position.
- Sales & marketing and development agreements with STS

Location

Pittsburgh Pennsylvania

Washington D.C. - 4hrs by car
New York City - 6hrs by car
Philadelphia - 5 hrs by car
Boston, Chicago - 1.5 hrs by Airplane
San Francisco - 4.5 hrs by Airplane

Selected Customers

Commercial

- Analog Devices
- Lucent
- IBM
- Qualcomm
- Seagate
- Corning
- Northrop Grumman
- Hitachi
- Japanese Consumer Companies

Universities and Labs

- US Army Laboratory
- NASA Goddard Space Flight Center
- National Institute of Standards
- Stanford
- Cornell
- Carnegie Mellon University
- University of Michigan
- Penn State University
- ITRI
- Ritsumeikan University
- University of Twente

XACTIX

Overview

- Corporate Overview
- Xenon Difluoride Etch Process
- MEMS Application Examples
- XACTIX Equipment

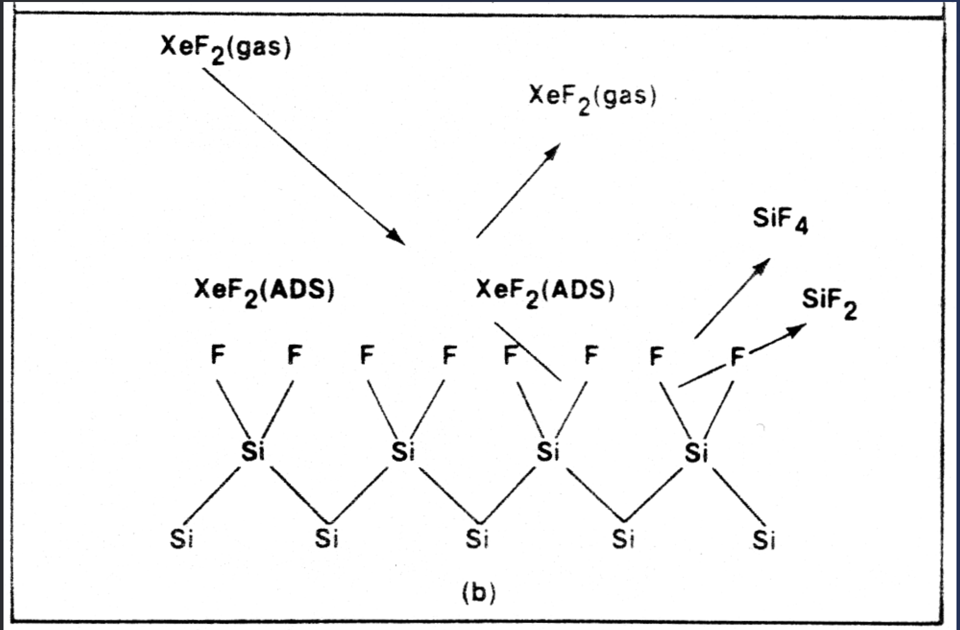
Xenon Difluoride

Isotropic Silicon Etch
For MEMS Release

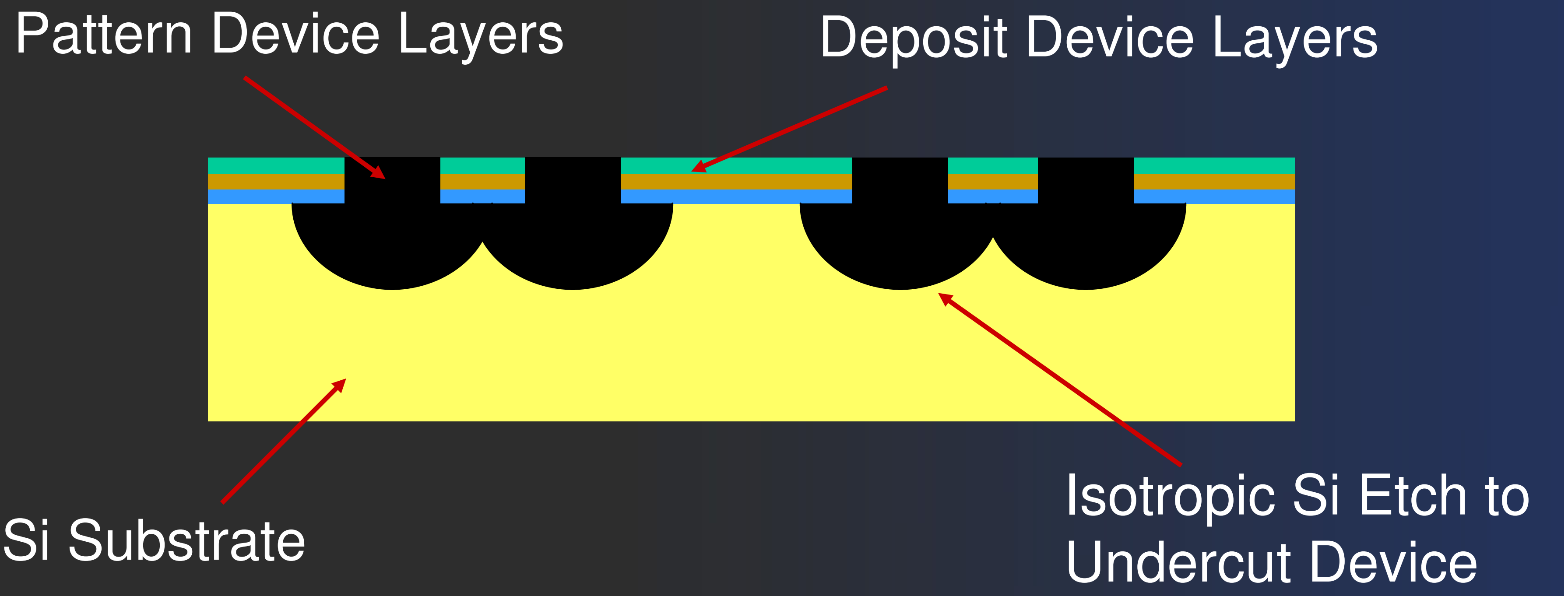
- Highly Selective MEMS Release
- No Stiction Problems
- Long Undercuts
- Release Using Nano-scale Holes and Release Layers

Etching Process

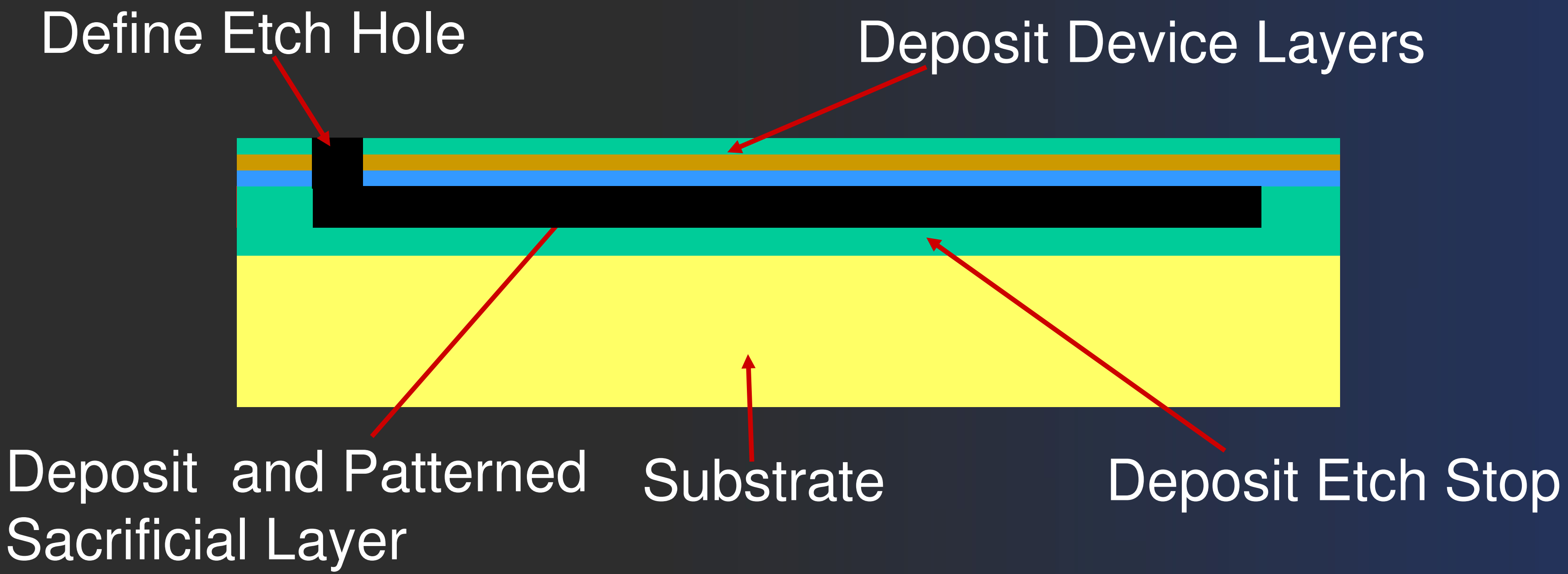
- $2XeF_2 + Si \rightarrow 2Xe + SiF_4$
- Selectively etches silicon, molybdenum and germanium.
- Isotropic etching
- Dry, vacuum based process (NO plasma or other activation needed)
- XeF_2 sublimates from solid crystals to form the vapor-phase etchant



Bulk Silicon Surface Micromachining



Surface Micromachining



As Late As Possible Release

- Once MEMS can move they can break

- Release after Capping
  - Avoid physical damage from capping process.
  - Go from release to hermetic seal under vacuum.
- Release at Packaging Fab
  - Avoid physical damage during transit
  - Avoid corrosion or stiction caused by moisture exposure after release.
- Release After Dicing
  - Avoid physical damage from vibration or heat and washing
- Release After Package Insertion and Wire Bonding
  - Avoid physical damage from vibration
  - Avoid exposure to packaging chemicals.

Etch Rates: Loading

- Typical Surface Micromachining Application with Si on 6” wafers: 2 to 3 um/min
- Small Chips: up to 10 um/min
- Fully exposed 6” wafer: 0.2 um/min

Reactive Materials

Material	**Selectivity to Si**
Si	1:1
Mo	2:1
Ge	Same or Faster than Si
SiGe	Same or Faster than Si

Conditionally Reactive Materials

- Ti, TiN, Ta, TaN, W, TiW
  - Etch rate depends on temperature.
  - Etch rates from 0 to 300 Å/min

Low Attack Materials

Material	**Typical Selectivity**
Thermal SiO_2	1000:1
Low Temperature SiO_2	1000:1
Si_3N_4	100:1
Gold	Low Amount of Attack Under Certain Conditions
Copper	
SiC	

Non Reactive Materials

Metals	**Compounds**	**Polymers and Organics**
Al	PZT	Photo Resists
Ni	MgO	PDMS
Cr	ZnO	C_4F_8
Pt	AlN	Silica Glass
Ga	GaAs	PVC (Dicing Tape
C	HfO	PP
	AlO	PEN
		PET
		ETFE
		Acrylic

Overview

- Corporate Overview
- Xenon Difluoride Etch Process
- MEMS Application Examples
- XACTIX Equipment

Application Areas

Sample of Applications

- RF Switches
- Projection Displays
- Reflective Displays
- Optical Attenuators
- Airborne Virus Detectors
- Chemical Sensors
- Pumps
- Oscillators
- IR Sensors
- Disk Drives
- Heaters/Micro Hot Plates

Sample Structures

- Switches
- Cantilevers
- Bridges
- Mirrors
- Membranes
- Channels
- Thermal Isolation Cavities

Poly-Silicon Micromachining

- High selectivity, excellent reach, fast etch times make XeF_2 an ideal solution for surface micromachining.
- Example of Common Commercial Application: Undercut = 30um to 100um, etch rate ~= 3um/min

Etch Hole ~1um^2

Device: Material Sandwich

Sacrificial Silicon: ~400nm Thick

Oxide Etch Stop: ~200nm thick

Poly-Silicon Micromachining

- High selectivity, excellent reach, fast etch times make XeF_2 an ideal solution for surface micromachining.
- Example of Common Commercial Application: Undercut = 30um to 100um, etch rate ~= 3um/min

Etch Hole ~1um²

Device: Material Sandwich

Sacrificial Silicon: ~400nm Thick

Oxide Etch Stop: ~200nm thick

Examples Using XeF_2

ADI Optical iMEMS Mirror

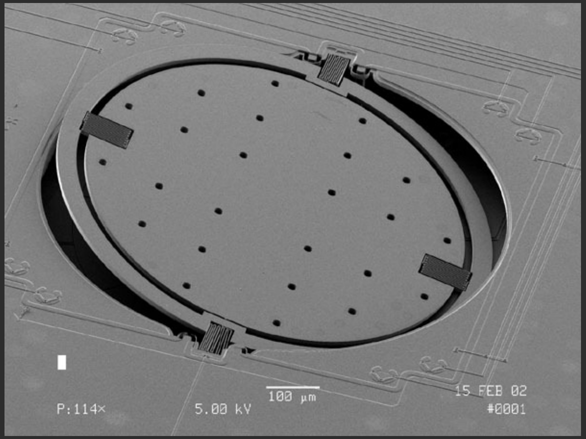


Image Courtesy of Analog Devices

Undercut Photoresist Using CMOS Poly 2

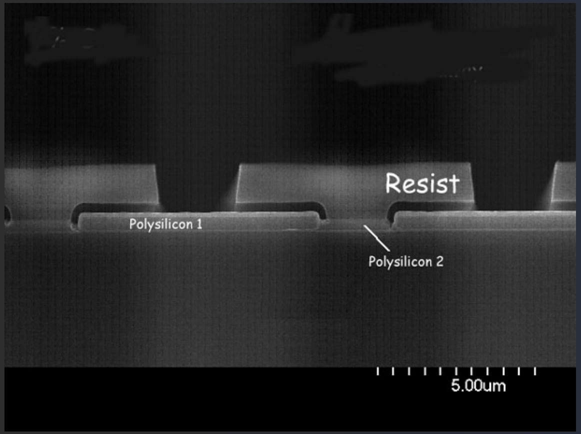


Image courtesy of XACTIX Customer

Cooling Tubes Etched at the Bottom of DRIE Trench

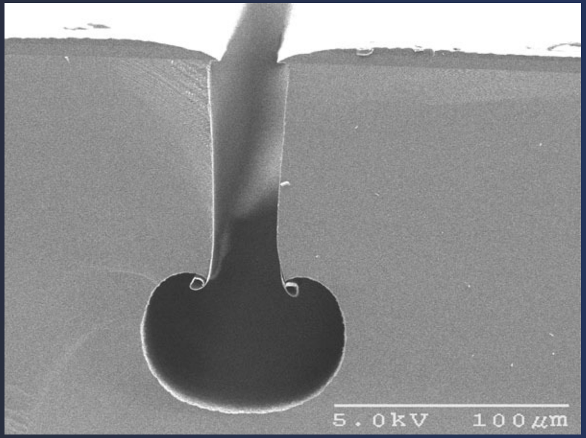


Image Courtesy of Carnegie Mellon University MEMS Laboratory

Examples Using XeF$_2$

QMT iMod Display

Image Courtesy of Qualcomm

RF Switch

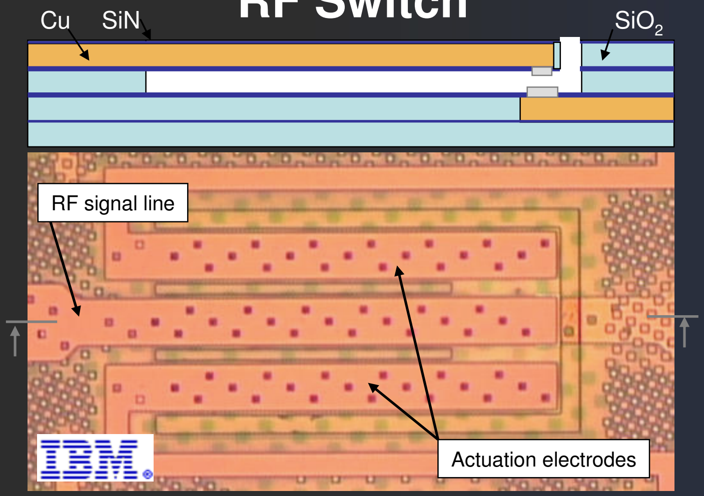


Image Courtesy of IBM

Poly SiC Membrane

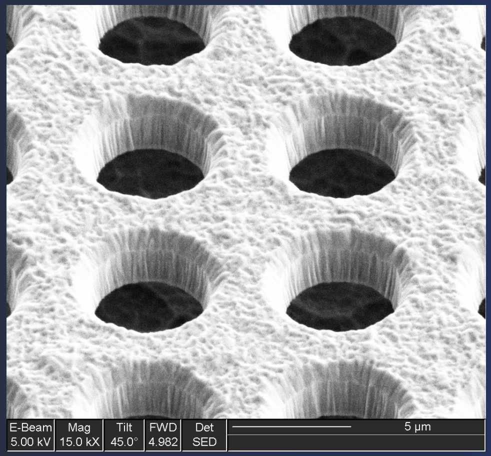


Image Courtesy of Dr. Roger Howe, Stanford University

Examples Using XeF_2

XACTIX

PZT Pump

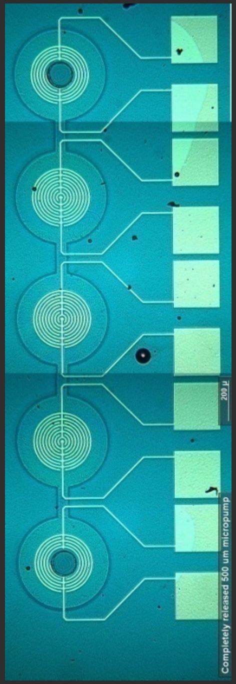


Image courtesy of The Pennsylvania State University and Northrop Grumman Corporation

Nano-Cantilever

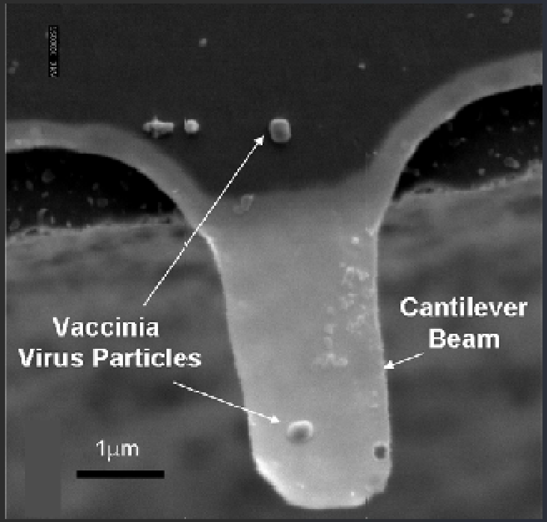


Image Courtesy of Dr. Rashid Bashir, Purdue University

Covered Trenches

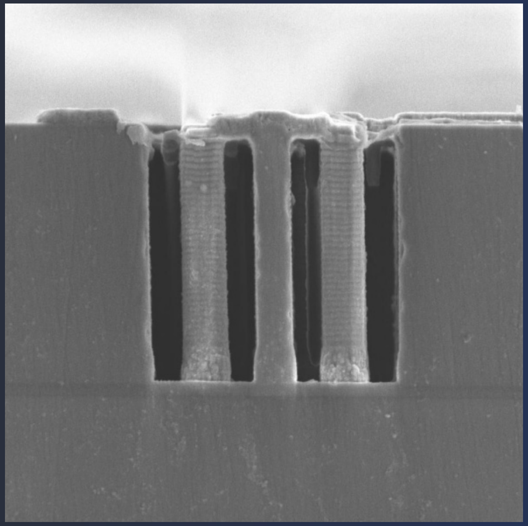


Image Courtesy of Dr. Oliver Brand, Georgia Tech

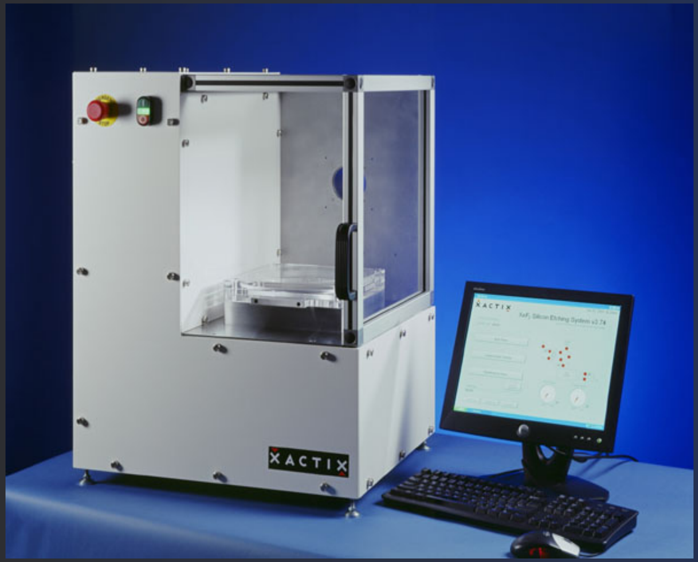
Overview

- Corporate Overview
- Xenon Difluoride Etch Process
- MEMS Application Examples
- XACTIX Equipment

XACTIX

Xetch X3: R&D Through Low Volume Production

Xetch e1: Low Cost R&D



STS XeF_2 Module

Volume Production

Leading Xenon Difluoride System for MEMS Volume Production

- Module for STS Wafer Handling Platform
- Multiple Wafer Handling Options
- 6” and 8” Capabilities
- Combine with Other STS Tools in Cluster Configuration.

Conclusion

- XeF_2 Isotropic Etch: Si, Mo, Ge
- Possible to etch W, TiW, Ti, Ta, TiN and TaN
- Very Low or No Attack on Most Other Materials
- Wide Range of Application Areas and Device Structures
- Wide Range of Equipment Options for R&D and Volume Production
- Unequaled Experience and R&D Using XeF_2