Unique Capabilities of Xenon Difluoride for Releasing MEMS

ADI Optical iMEMS Mirror

Very long undercuts of silicon device achieved using very thin oxide mask layers

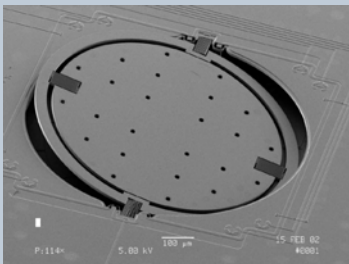

Image Courtesy of Analog Devices

Tube Etched at Bottom of Deep RIE Trench.

C_4F_8 Polymer used to mask sides of trench during isotropic etch

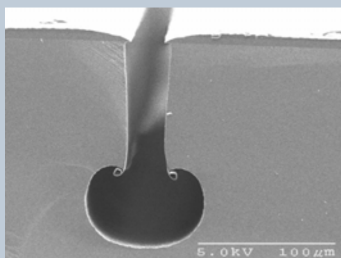

Image Courtesy of Carenegie Mellon University MEMS Laboratory

Isotropic etching using xenon difluoride is an ideal solution for releasing MEMS devices. It provides numerous unique advantages and capabilities compared to wet and plasma etch options. The following describes a few of these unique capabilities.

Reactive Materials

XeF_2 can be used to istoropically etch Si, Mo and Ge.

Selectivity to a Wide Variety of Materials

There is no other isotropic etch that is selective to so many materials. As MEMS get more complicated they contain devices made from multiple or non standard materials. Devices can be made using any combination of silicon dioxide, silicon nitride, most metals and dielectrics, polymers, etc. As examples XeF_2 is being used to manufacture products with mixed dielectric membranes, exposed metals and polymer membranes.

Long Undercuts

Because of its selectivity and excellent reach, XeF_2 can be used to make very long undercuts with little or no degradation of etch stop, mask or device layers. As an example, silicon dioxide is a very popular mask material because of its better than 1,000 to 1 selectivity over silicon, and has been used to achieve very long undercuts (well over 100um) and to protect extremely small or thin devices (less than 30nm in dimension).

Etching Through Small Holes and Tight Spaces

Because XeF_2 is a dry etch there are no surface tension or bubble related problems with etching through small holes or in tight spaces. XeF_2 has been used to etch through holes as small as 25nm in diameter. A common commercial application uses the Xetch to remove sacrificial silicon only 300nm to 400nm thick through 1um to 5um holes, requiring more than 30um to 100um of undercut at etch rates of 2um to 3um a minute.

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ZnO Cantilever
Exploited selectivity to multiple exposed materials including ZnO, Al and SiO_2

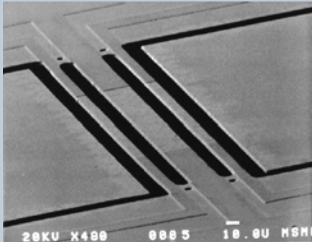

Image Courtesy of Dr. Don DeVoe
University of Maryland

Nano Cantilever for Virus Detection
30nm thick silicon cantilever released using very thin oxide mask and XeF2

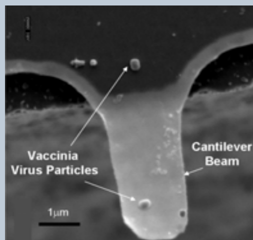

Image Courtesy of Dr. Rashid Bashir
Purdue University

Optical Attenuator
Exploited selectivity to silicon nitride and aluminum

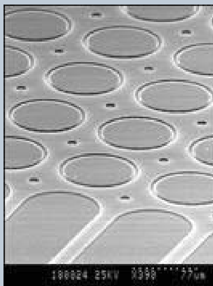

Image Courtesy LIGHTCONNECT, Inc

Eliminating Stiction During Release
Being a dry, vapor phase etchant, XeF2 avoids many of the problems associated with wet etch processes.

Dry Etching With Photoresist Mask.
XeF_2 is very gentle on photoresist so you can use it as a mask on extended etches.

Combined Isotropic and Anisotropic Etching
XeF_2 shows minimal attack on polymers. In particular, it does not significantly attack the passivation layer used in the Bosch process for deep anisotropic silicon etching. As a result, XeF_2 is an ideal process for etching round cavities or tubes at the bottom of deep high aspect ratio holes or trenches in a silicon wafer.

Etching in the Package or After Bonding
XeF_2 has been used successfully to release MEMS after they have been bonded and packaged.

Design for Higher Yields and Tighter Specifications
The high selectivity to different materials, especially silicon dioxide, allows a designer to easily incorporate etch stops or use existing buried structures as etch stops for undercutting. Since there will be almost no attack on the etch stop or the device being released it is possible to overetch without damage. This means that yield losses due to unreleased and overetched devices can be reduced to zero. It will also assure that the geometries of the undercut are completely uniform allowing much tighter design specification.

Fast Etch Rates for Widely Selective Gas Phase Etching
XeF_2 etch rates are very dependent on the amount of exposed silicon. By avoiding unnecessary exposed silicon and by using the correct recipe, fast etch rates can be achieved. Because you can use a multitude of materials including photoresist in very thin layers as masks and etch stops, this is easy to do. Undercutting 3um to 4um a minute is readily attainable.

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