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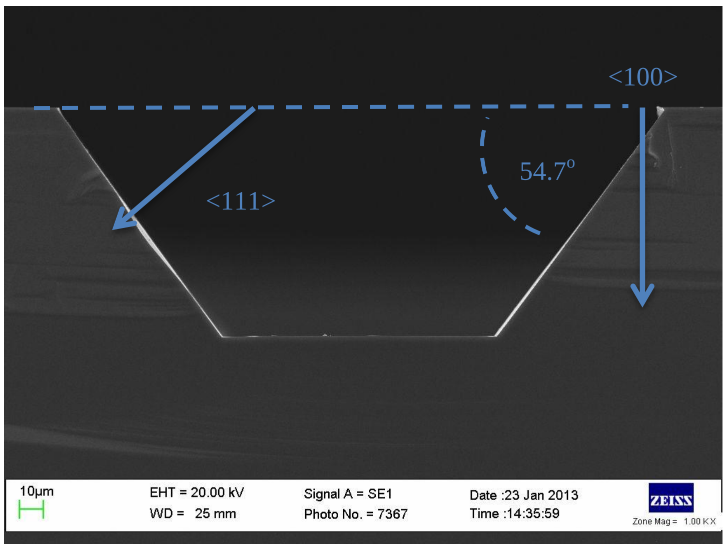
KOH Etching of Bulk Silicon

KOH etching is a well-documented anisotropic Si etch process. The process most often takes advantage of the etching ratio between the crystal planes in the silicon lattice. The sidewalls of the etch are defined by the <111> plane, and the <100> plane is etched at a 54.7^{o} angle relative to the <111> plane. Due to the nature of this etch, careful thought must be taken when designing a mask as well as ensuring the proper alignment during lithography. The patterning and etching of other wafer orientations (mainly <110> and <111>) can be advantageous when fabricating free-standing structures.



250um wide trench, etched to 89.3um, <100> orientation

The standard process in the nanoFAB is to use a 32% (w/w) KOH solution with a volume in the reaction vessel ~1500mL in order to cover the heating pad surrounding the vessel. Using the 45% stock solution, a 961mL volume of KOH is added to 569mL of H2O to reach a 32% concentration. Refer to the calculation spreadsheet for more information. Varying the concentration of the KOH may be performed, but doing so will change a number of factors during the etch (rates, selectivity, uniformity, etc)

150mL of IPA was added to the solution in order to minimize the surface roughness. Ideally IPA is added to saturation (where a visible sheen can be seen on the surface), but the IPA will evaporate over the course of the etch.

The test wafer was of <100> orientation, P type, B doped, with a resistivity of 1-10ohm-cm. The wafer was coated with ~100nm of LPCVD SiN as an etch mask. The masking layer was patterned using standard lithography steps, and etched in the STS RIE. The remaining resist was stripped using the Branson barrel etcher.

As a standard etch test, the 32% KOH solution was prepared, and heated to 85C. The stirrer setting was set to 60rpm using the disk style stir bar. The wafer was etched for a total of 60 minutes. The resulting etch depth was measured at several points across the wafer, as well as the thickness of SiN layer pre and post etch.

Results:

Etch Rate = 1.6um/min
Selectivity = 49000:1 (using stoichiometric LPCVD SiN)
Uniformity = 6.8%

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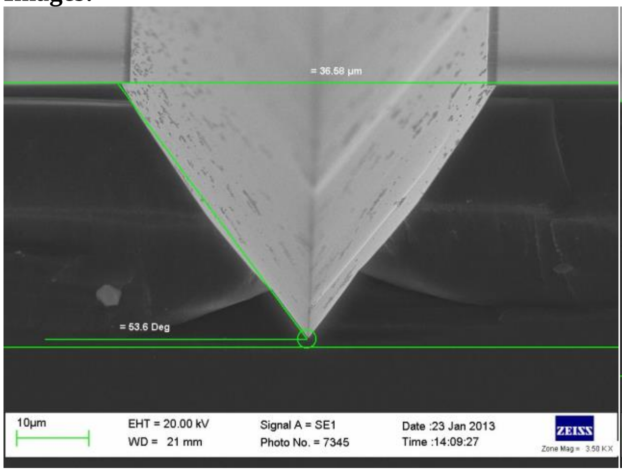
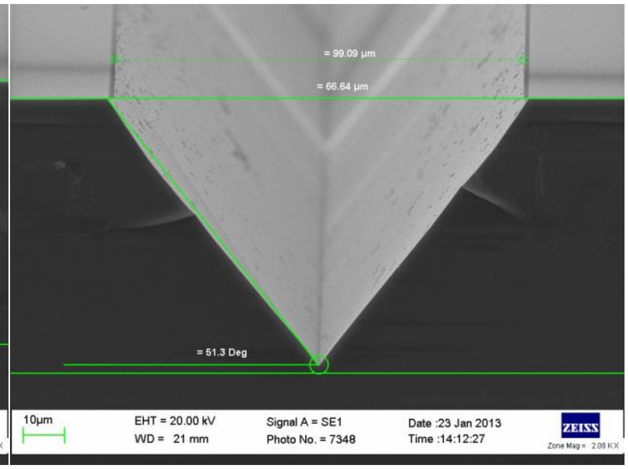
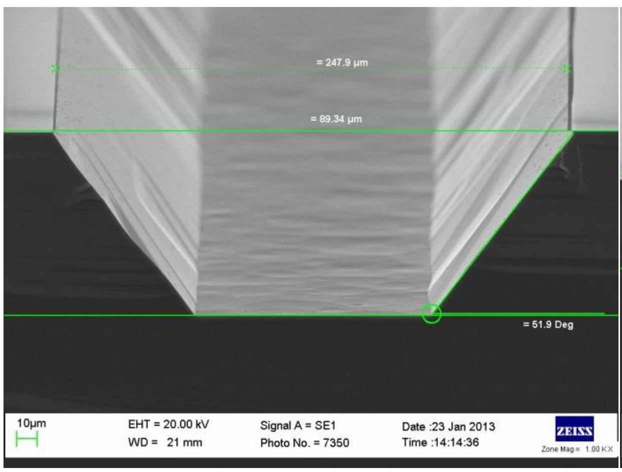
Images:



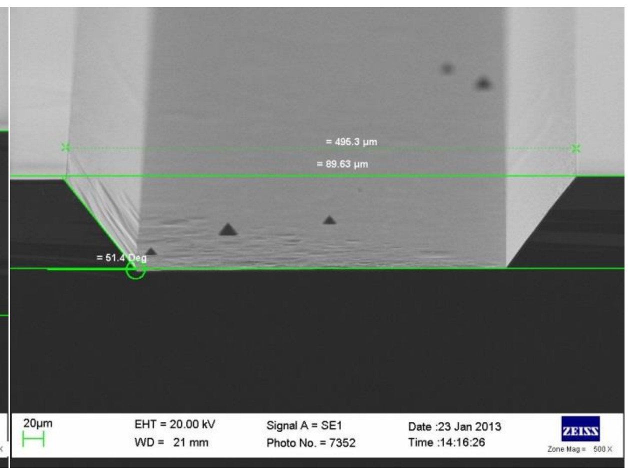
50um trench etched to 36.6um



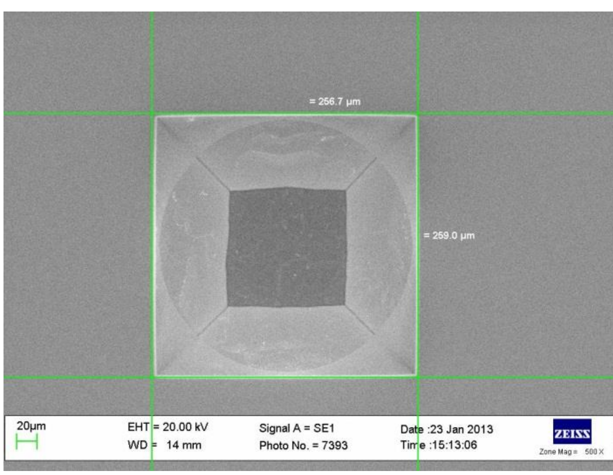
100um trench etched to 66.6um



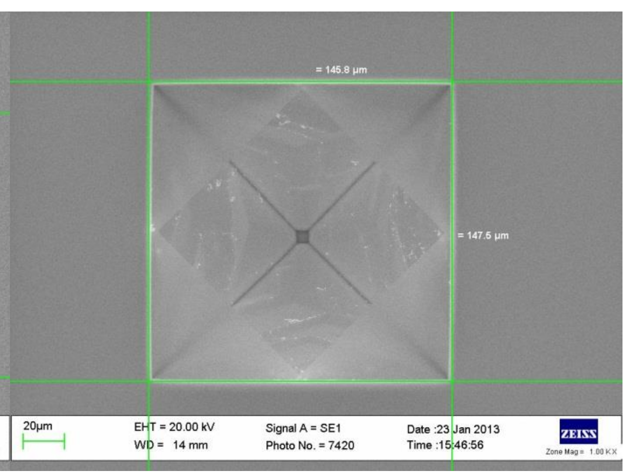
250um trench etched to 89.3um



500um trench etched to 89.6um



250um diameter circle



100um square, rotated 45^{o} to <100> plane

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Notes:

Other Etch Data:

Data from a separate etch, where a full boat containing 10 patterned wafers were immersed in the bath. The temperature was under the 85C setpoint for the bulk of the etch, which may have had some effect on the etch. The etch rate dropped for the above posted rate on page 1 to 0.82um/min, and the uniformity improved to 4.2% across all wafer (excluding the <111>, where there were rate differences across individual features).

Selectivities (Si:X):

PECVD SiN	= 7300:1
LPCVD:	
-Stoichiometric	= 29000:1
-Low Stress	= 33000:1
Thermal SiO2	= 180:1

Material Compatability

Known non-compatible materials include photoresists, Al, Al_2O_3, and Ti/W. Do not immerse these materials into KOH. Other materials may be somewhat compatible, but may still etch, swell or soften on exposure to KOH. If the compatibility of your material is unknown, it must be verified before beginning the etch process. A good reference paper for material compatibility is - Etch Rates for Micromachining Processing—Part II, Kirt R. Williams et al., JMEMS 2003.

The following formula may be useful to determine feature sizes of the final etch, or what is required when designing a mask to achieve a final feature size (for <100> orientation): $A = d + 2 \times T_w \times \cot 54.7$

Where: A = size of feature on mask
d = desired feature size on processed wafer
Tw = bulk Si etch depth
Cot 54.7 = 0.708039

Eg. A 500um wide channel etched to a depth of 100um will have an unknown final width at the bottom of the channel:
500um – 2 x 100um x 0.708039 = 358.4um