Top reasons to use the IntelliSuite Cleanroom Package

1.Microloading (loading effect) and DRIE-lag (ARDE) simulation

2.Blueprint – Professional, user-friendly mask editor with built in DRC

3.Fast simulations that match the experiments

4.Extensive database

5.High-index off-cut substrates beyond standard wafer orientations and flats

6.Different etch rates for Si(111) depending on the inclination angle

7.Characterize your etchant to understand how it etches

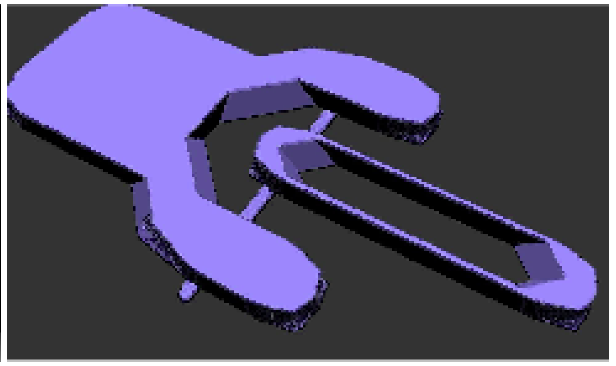
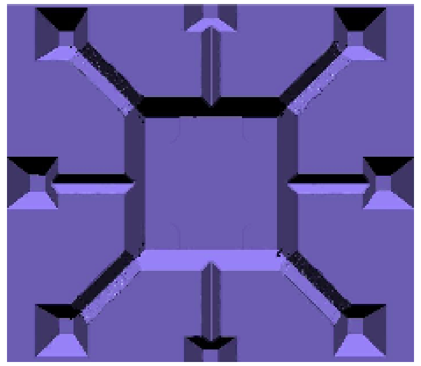
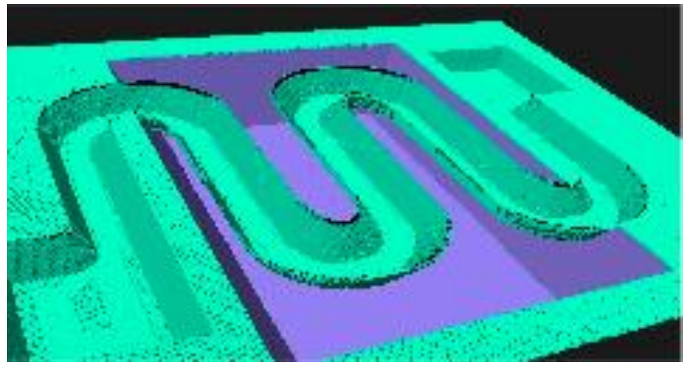
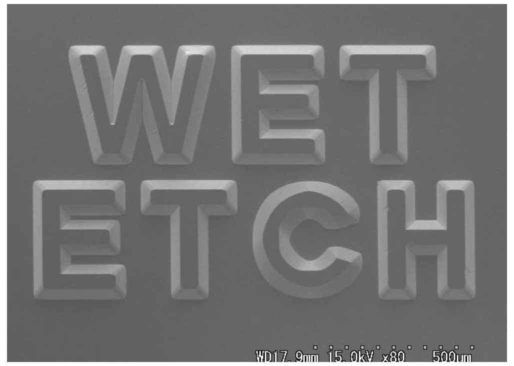
8.Convex corner undercutting and compensation

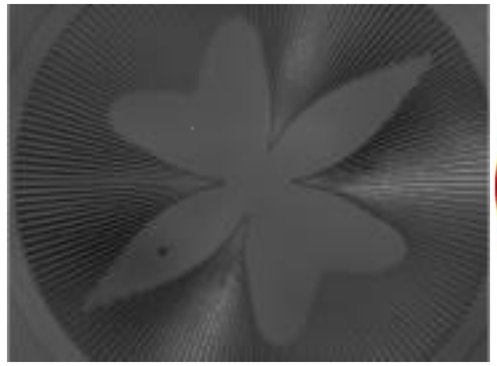
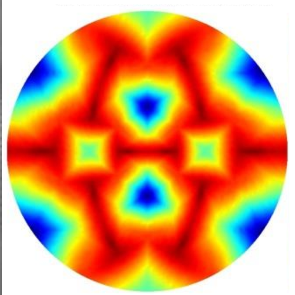
9.Complex processing with multiple etching steps

10.Submicron, nanoscale etching

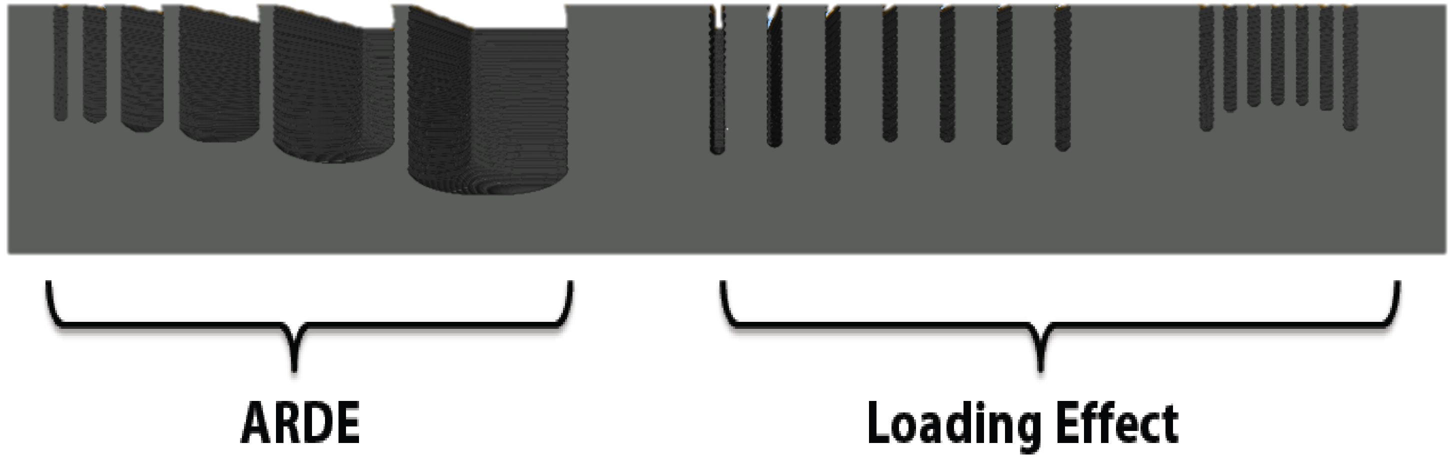
11.Diffusion-limited isotropic etching

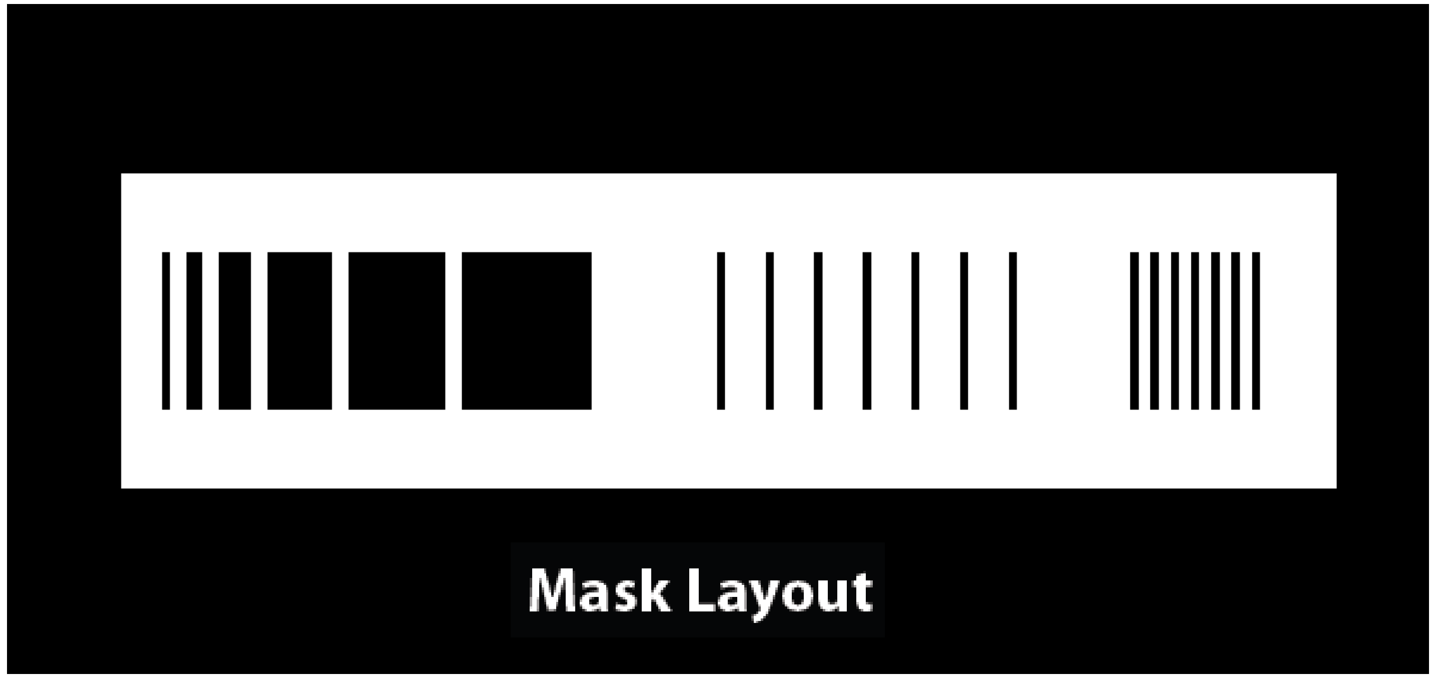
12.Up to three cross-sections with geometrical measurements

1. Microloading (loading effect) and DRIE-lag (ARDE) simulation

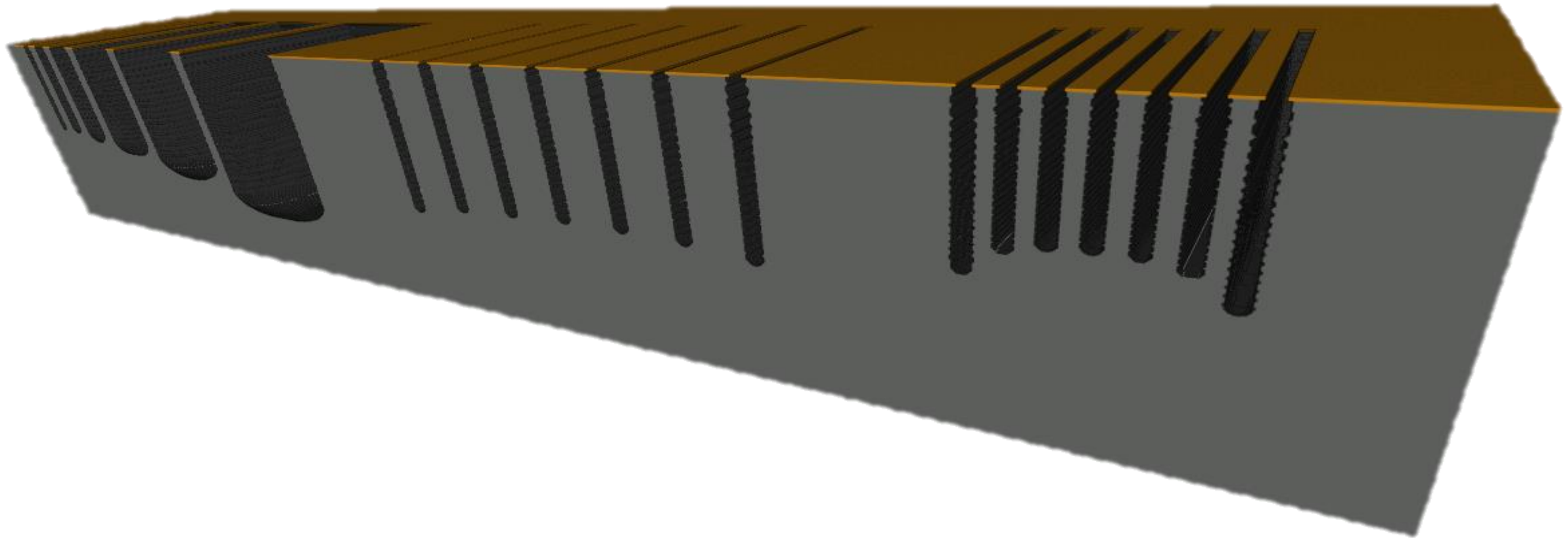




Microloading (loading effect) and **DRIE-lag** (ARDE) are two phenomena that must be taken into consideration during DRIE processes. IntelliSense has made groundbreaking advancements in DRIE simulation. The new process simulation tools handle both phenomena with unparalleled accuracy.

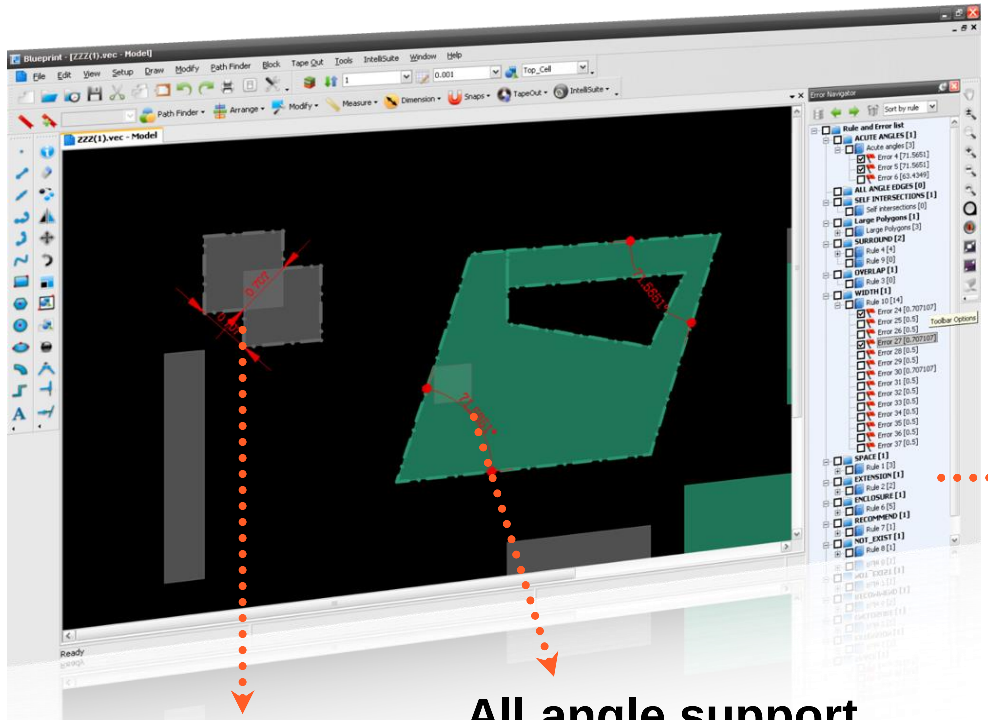
-**Microloading**: The etch rate is dependent on the density of the exposed area at the feature scale. Equally wide trenches located close together are etched less deeply than similar trenches located farther apart.

- **Aspect Ratio Dependent Etching (ARDE):** Etch rate reduction as a function of etch time for a given trench width. This occurs due to slower transport in the Z direction as the trench aspect ratio increases.



2. Blueprint – Professional, user-friendly mask editor with built-in DRC

Design Rule Check (DRC)



Easy error navigation

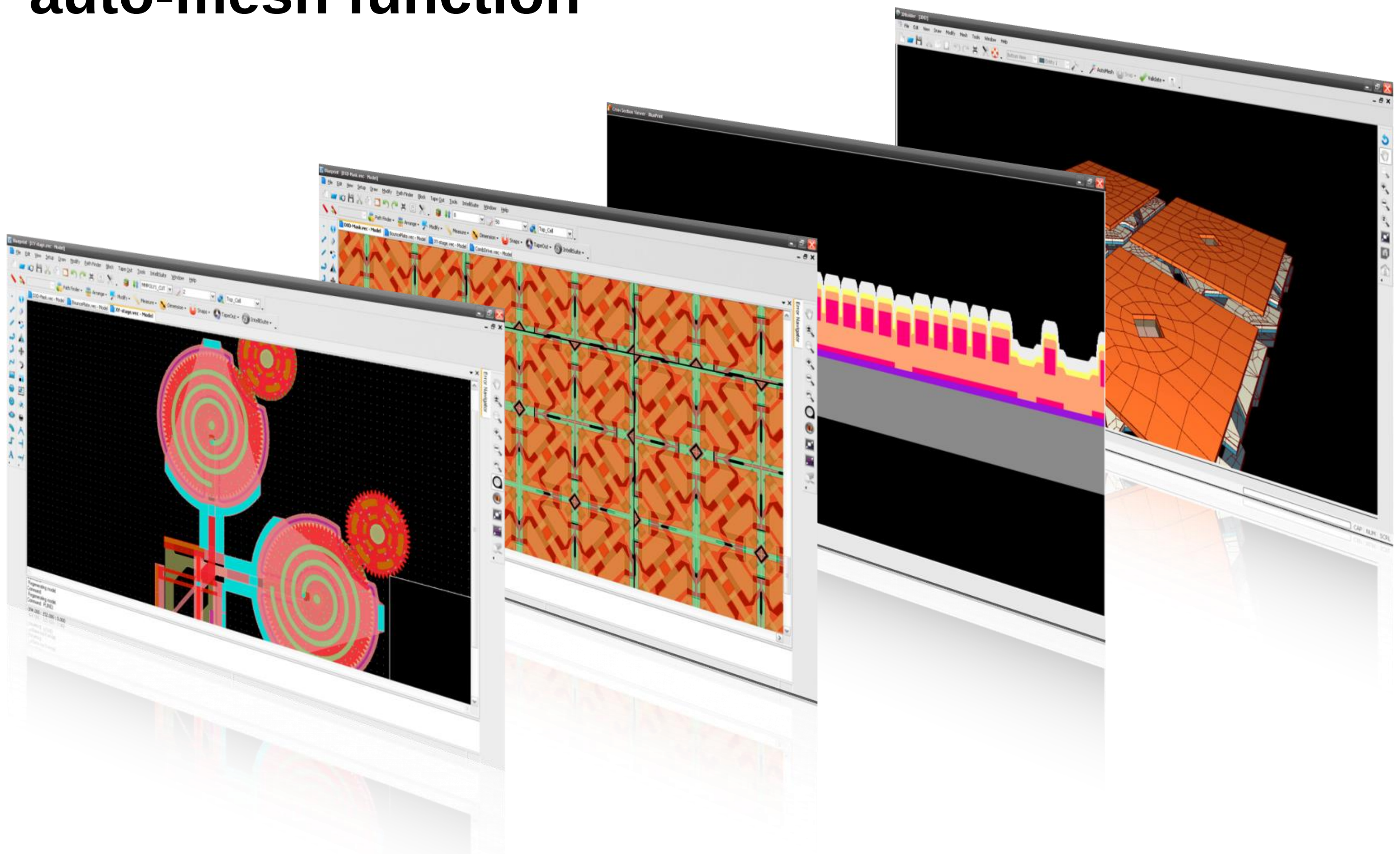
Intuitive error markings

All angle support

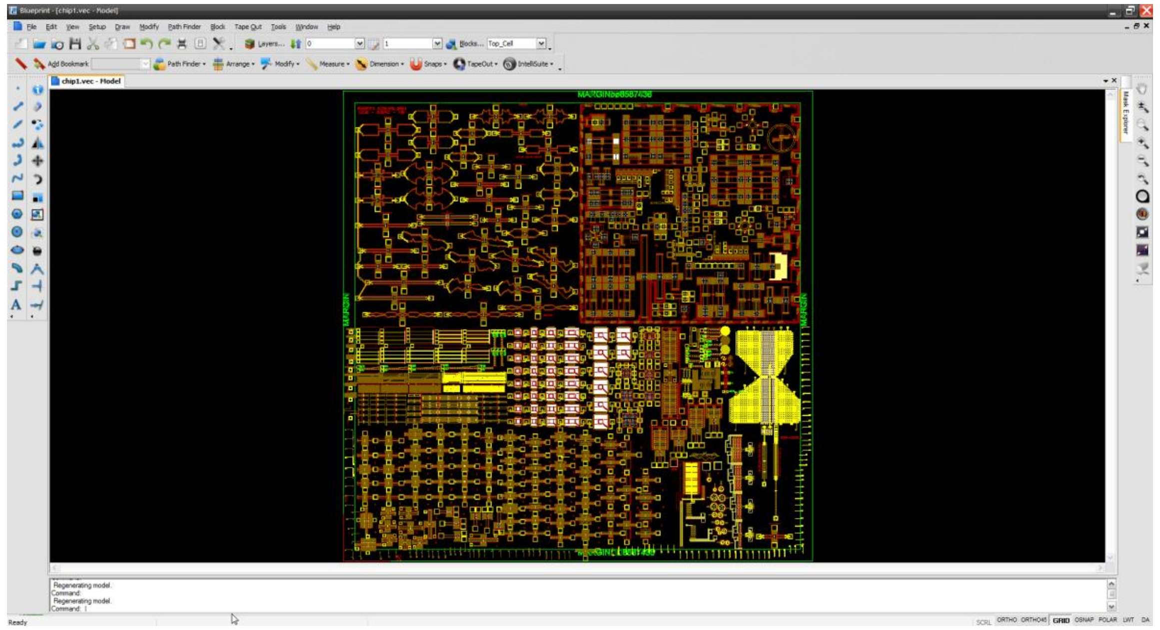
Tape Out

Image import options:
BMP, PNG, JPG ► VEC, GDS-II, DXF

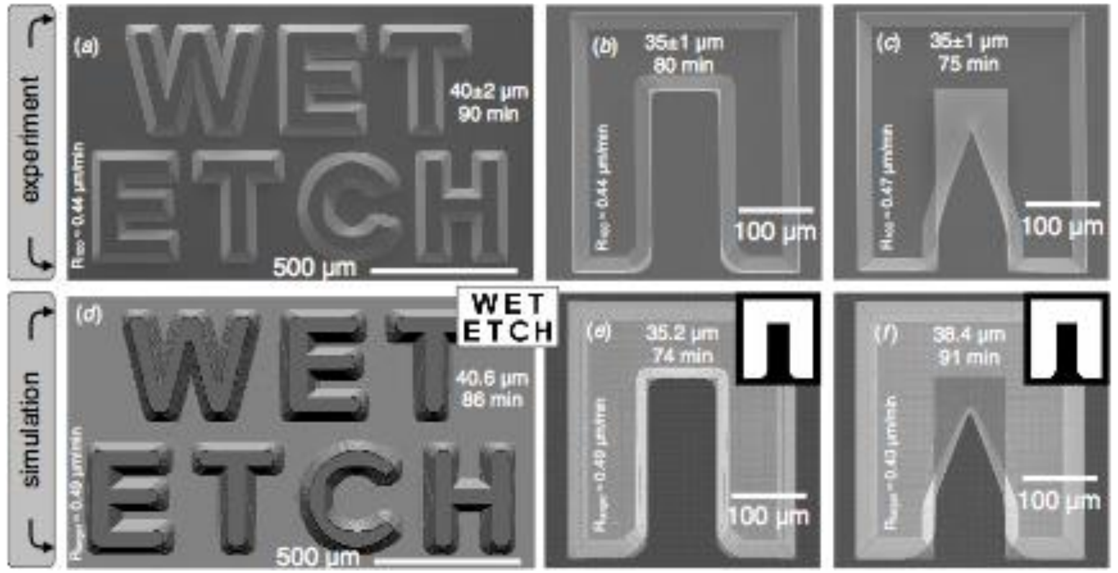
Rapid cross-section viewer and auto-mesh function

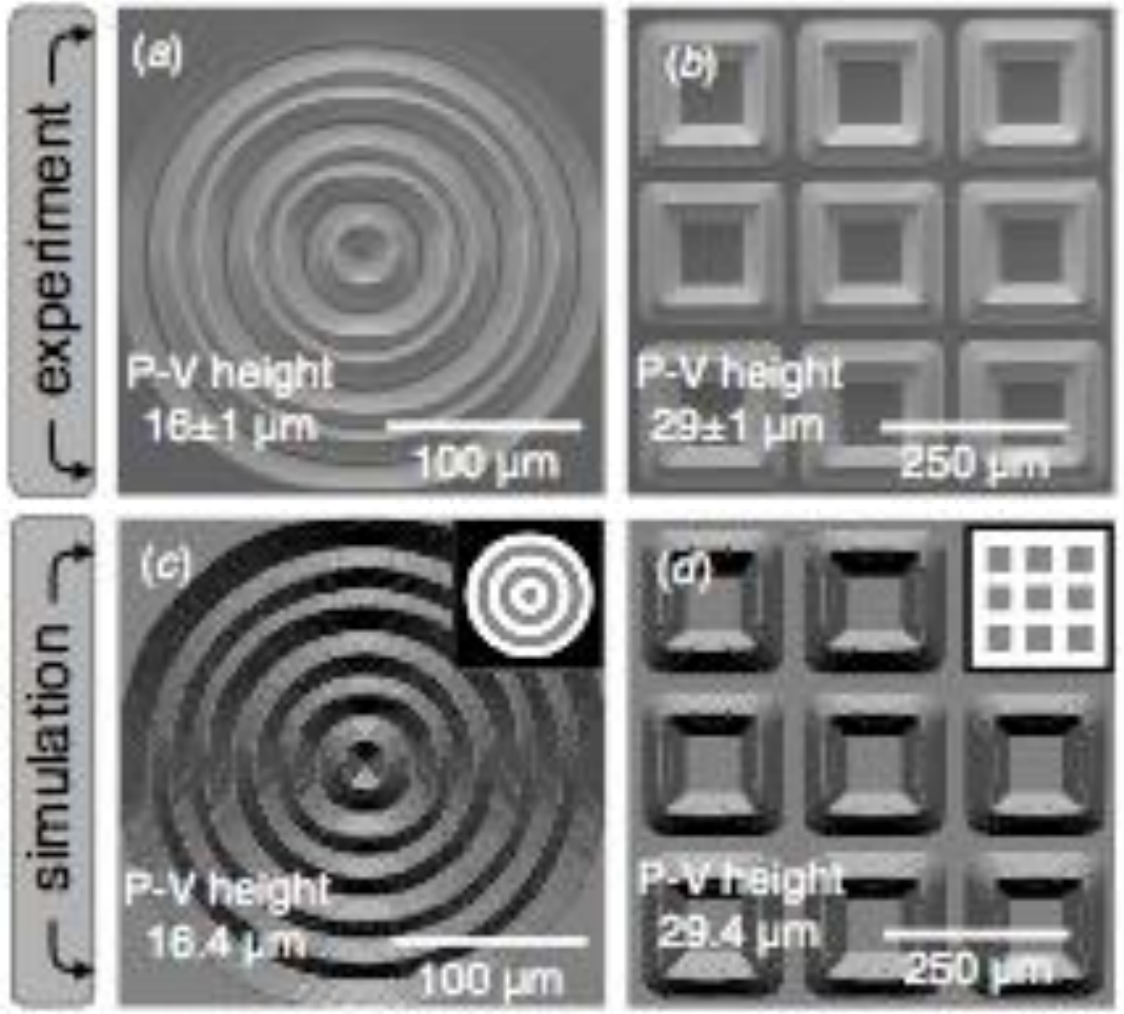


Large industrial layout file support



3. Fast simulations that match the experiments





Gosalvez *et al.*, *JMM* **21** (2011) 125007

IntelliEtchG, the GPU version of **IntelliEtch,** uses Nvidia graphics cards in order to accelerate the calculations. In addition to displaying the systems as animations in real time during the actual calculations, **IntelliEtchG** typically finishes a simulation within seconds. In comparison, traditional simulators need several minutes or tens of minutes to complete the same task.

Computing time						
CPU simulator	987 s	3288 s	529 s	1284 s	2362s	6782 s
GPU simulator	6,58 s	13.76 s	3.53 s	7.79 s	13.48 s	18.9 s
Speedup	150.0 x	238.9 x	149.8 x	164.8 x	170.0 x	358.8 x
White percentage	16.01%	16.14%	17.58%	34.31%	40.95%	65.08%

Processor: Intel Core i7 920 2.66GHz (~300€)
Graphics card: Nvidia GeForce 9800GT 512MB (~100€)

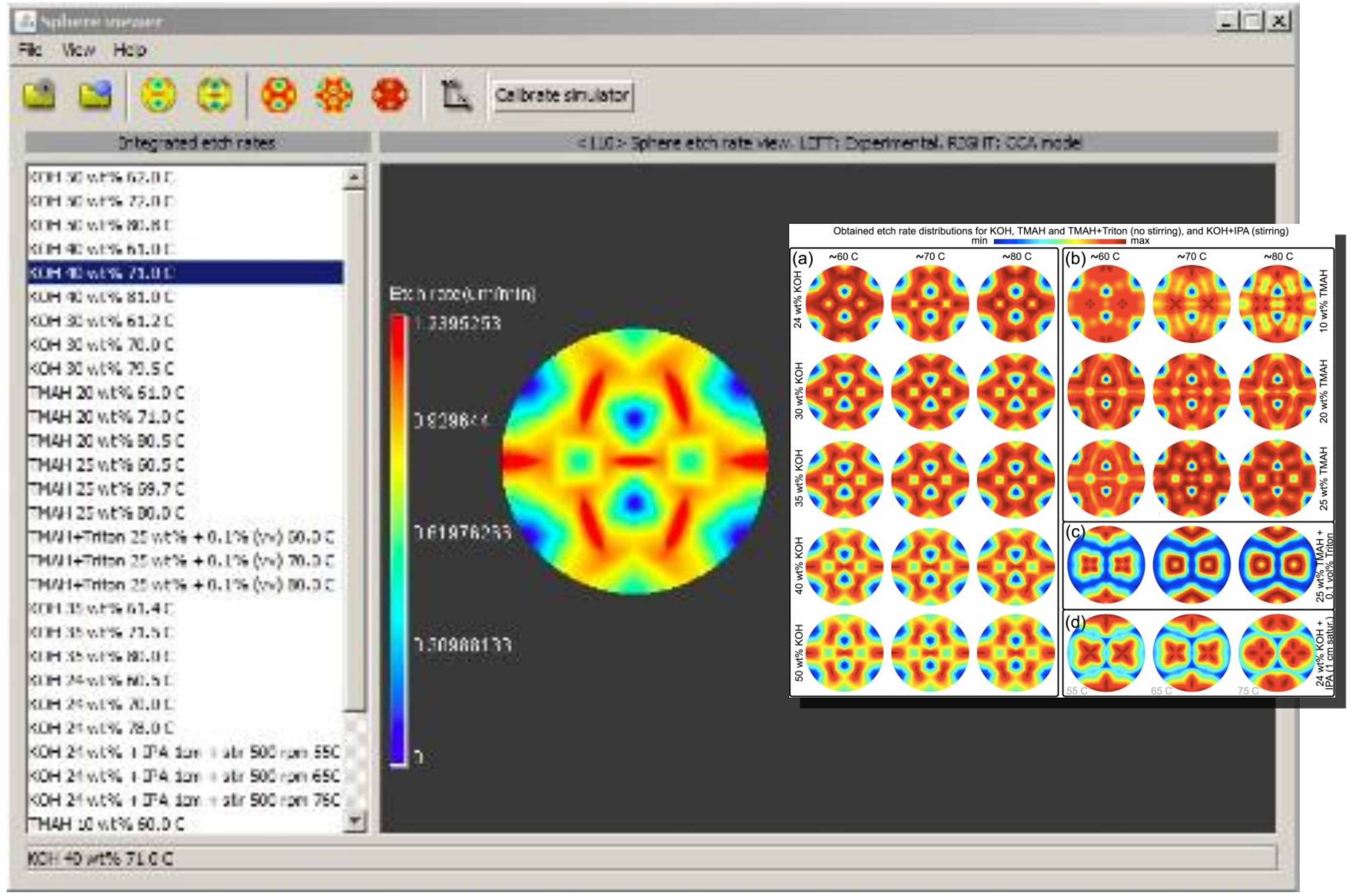
Simulation of <100> surface, 512 unit cells in the longest axis.
OS: Windows 7 64-Bit, BT-CTS time steps, SIMODE_30WT_80C etchant

Unlike traditional simulators, **IntelliEtch** has the ability of simulating other etchants than KOH. For TMAH and TMAH+Triton, the left figures provide an overview of the simulation accuracy.

4. Extensive database

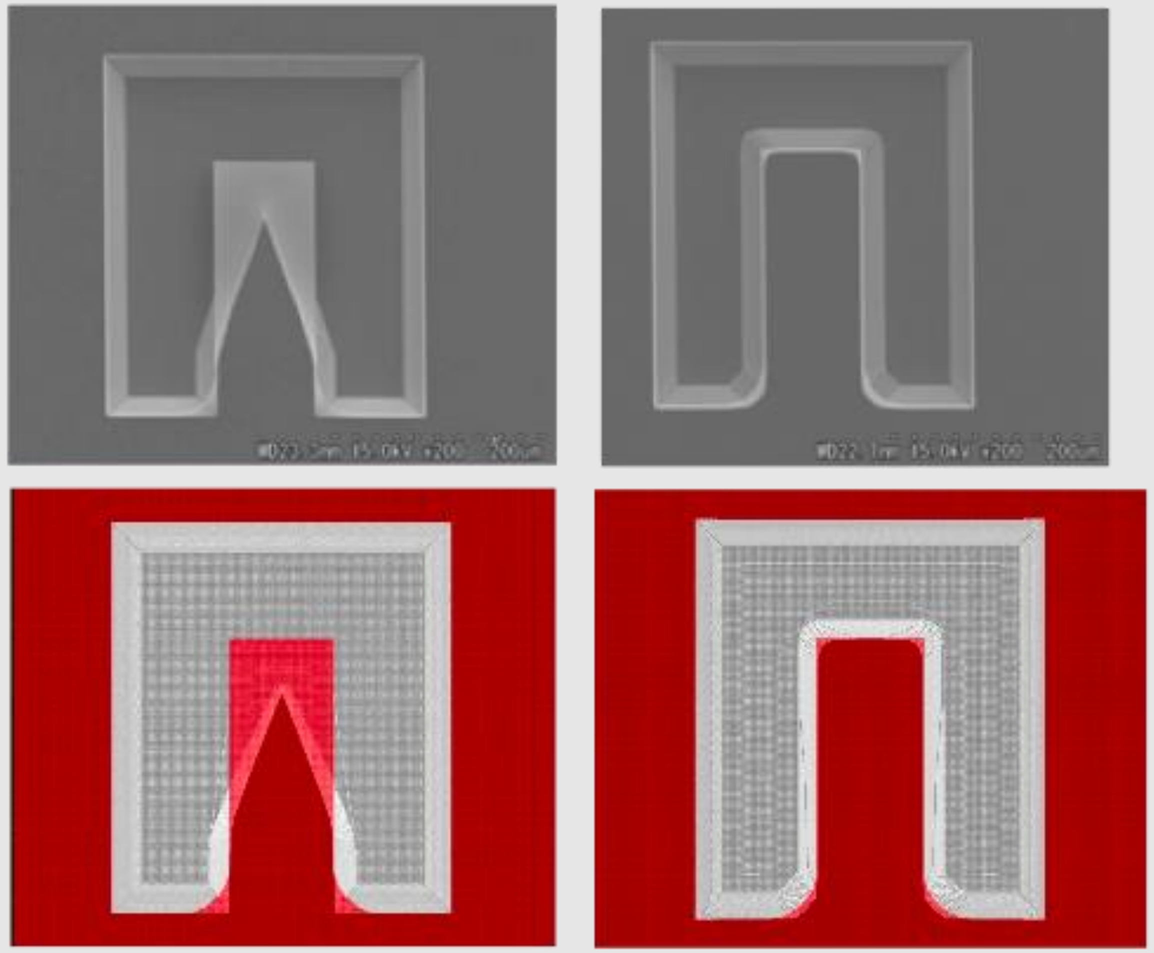
IntelliEtch has been calibrated to simulate anisotropic etching in a wide range of technologically relevant etchants.

Understand the etching process for a wide range of concentrations and temperatures in dramatically different etchants, such as KOH and KOH+IPA, or the CMOS compatible TMAH and TMAH+Triton, and isotropic etching. In addition, the user can calibrate the tool and perform simulations for new etchants.



	KOH+ IPA	KOH					TMAH			TMAH +Triton	NH_4HF_2
Conc. wt %	24	24	30	35	40	50	10	20	25	25	Saturated
60 C	✓(55C)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
70 C	✓(65C)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
80 C	✓(75C)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
											✓ 85 C

Experimental conditions for which IntelliEtch has been calibrated.
White: silicon etchants. Yellow: quartz etchants



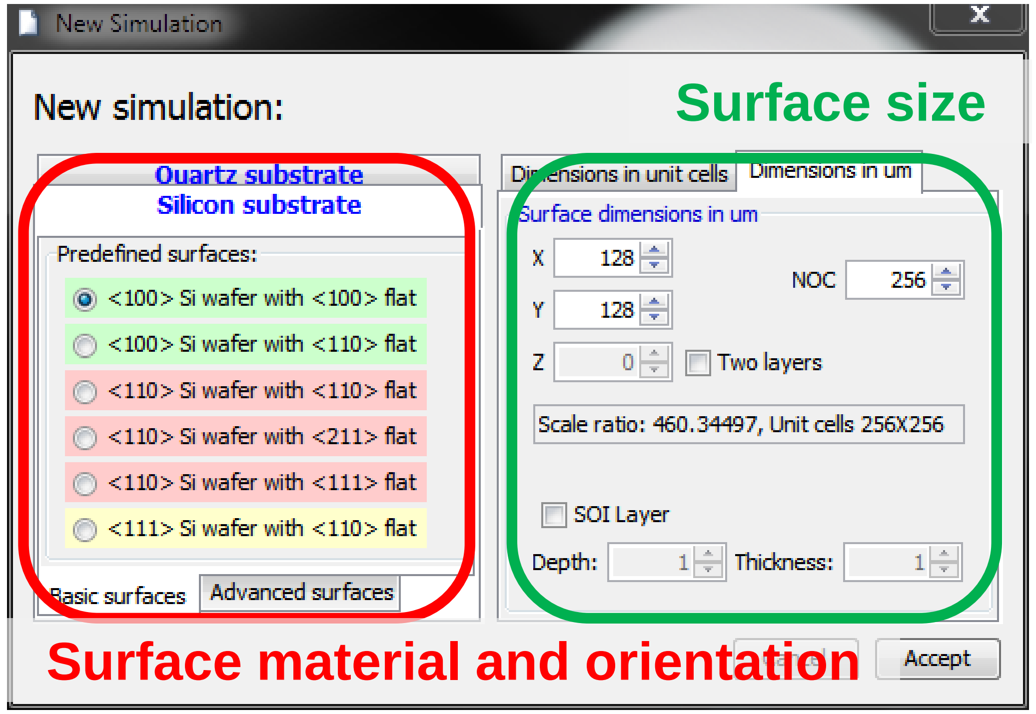
Experiment and simulation by **IntelliEtch** revealing markedly different results for different etchants:

Left images:
TMAH, large underetching

Right images:
TMAH+Triton, no underetching

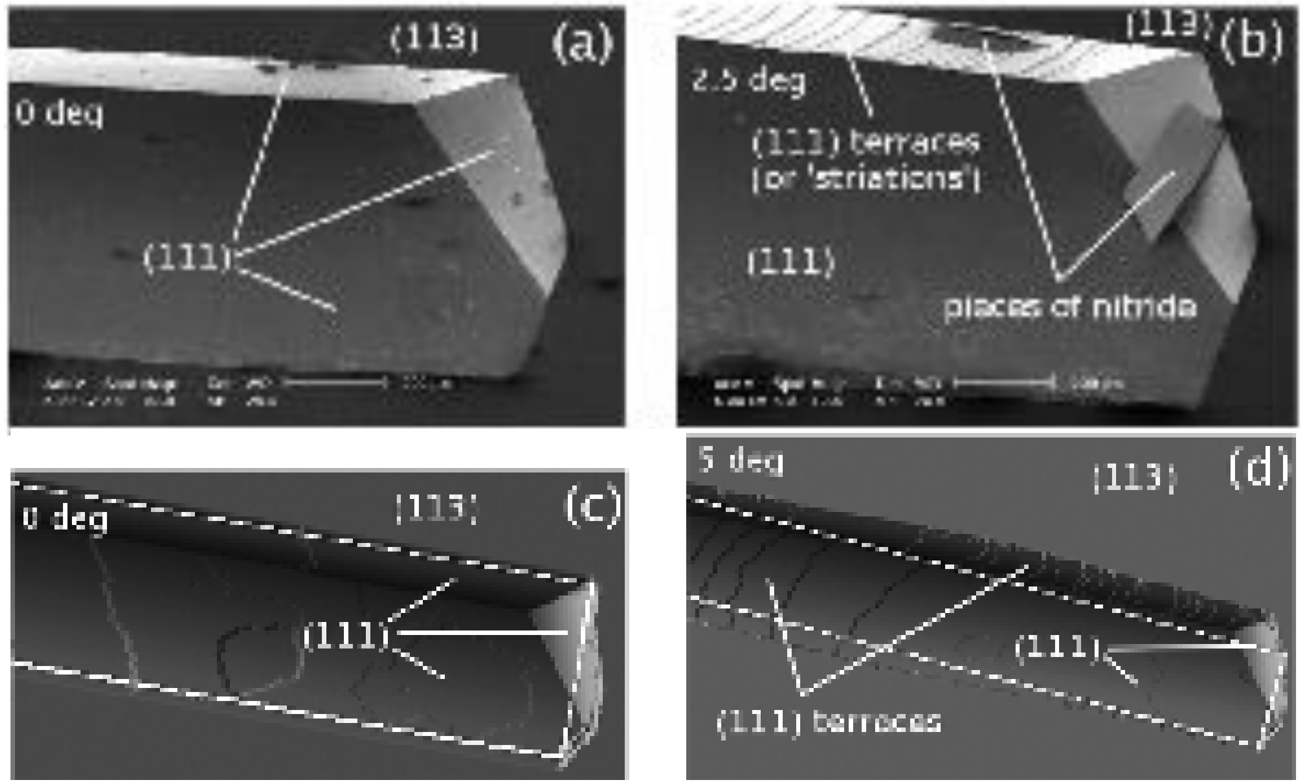
Top images: Experiment.
Bottom images: Simulation.

5. High-index off-cut substrates beyond standard wafer orientations and flats



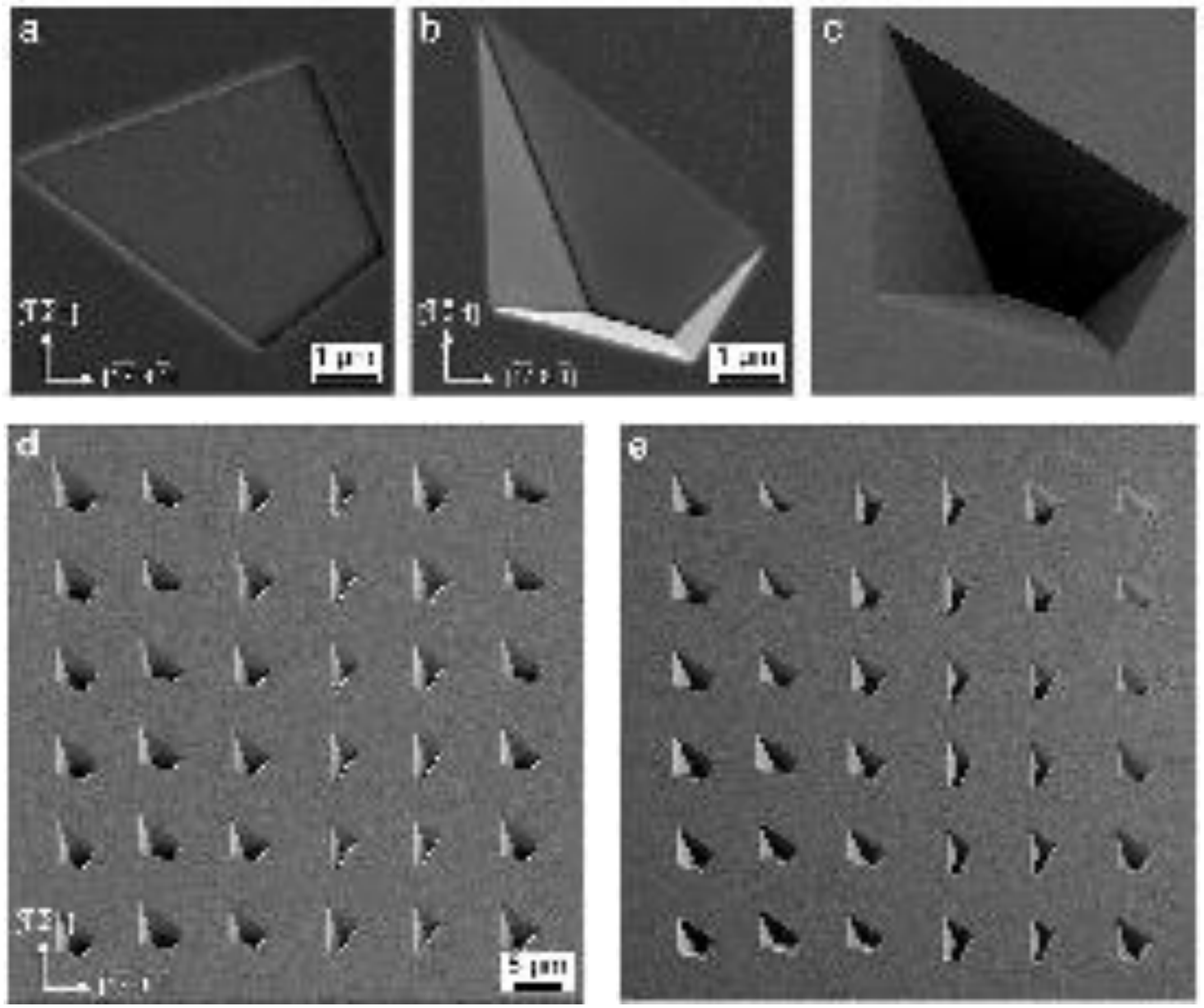
Choose between the standard wafer orientations and flats for silicon and quartz, or define unusual substrate orientations by specifying the Miller indices (hkl) for silicon and (hkil) for quartz. Understand how etching proceeds on high-index off-cut silicon and quartz substrates, *e.g.* for the fabrication of mold structures or chiral surfaces and nanoparticles.

Experiment and simulation by **IntelliEtch** revealing the formation of stepped side-walls on Si(113) wafers with misaligned masks. Top images: experiment. Bottom images: simulation by **IntelliEtch**.



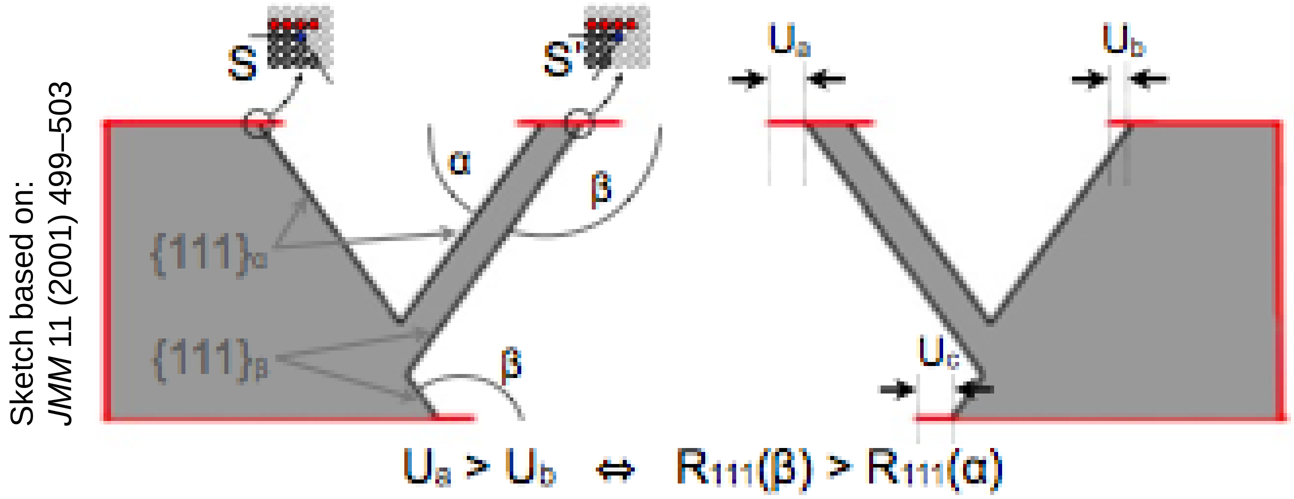
Werkmeister *et al.*, *JMEMS* 15 (2006) 1671-1680

(a) Kite-shaped mask on a Si(137) wafer, (b) asymmetric cavity obtained by etching in 30 wt% KOH, (c) simulation by **IntelliEtch**,(d) array of asymmetric cavities, (e) simulation by **IntelliEtch**.



McPeak *et al.*, *Nano Lett.*, 2014, 14 (5), pp 2934–2940

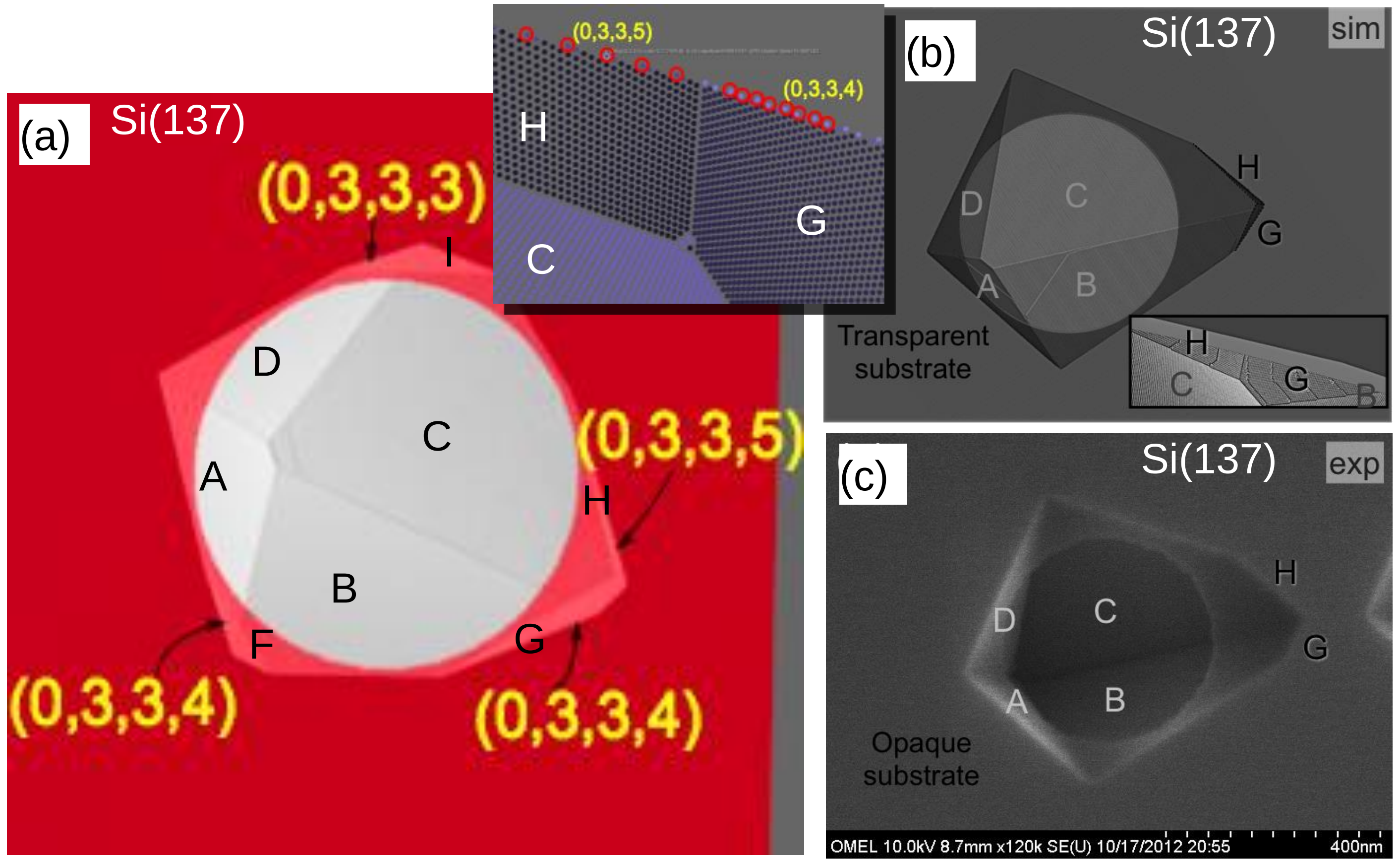
6. Different etch rates for Si(111) depending on the inclination angle

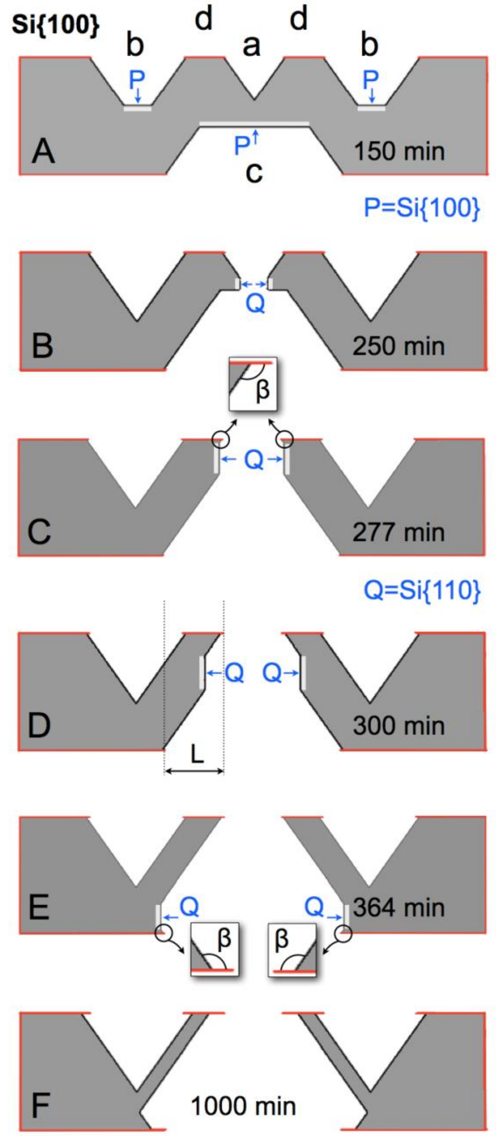


The etch rate of Si(111) is larger for (111) facets that make an obtuse angle (β > 90° > α) with respect to the masking layer.

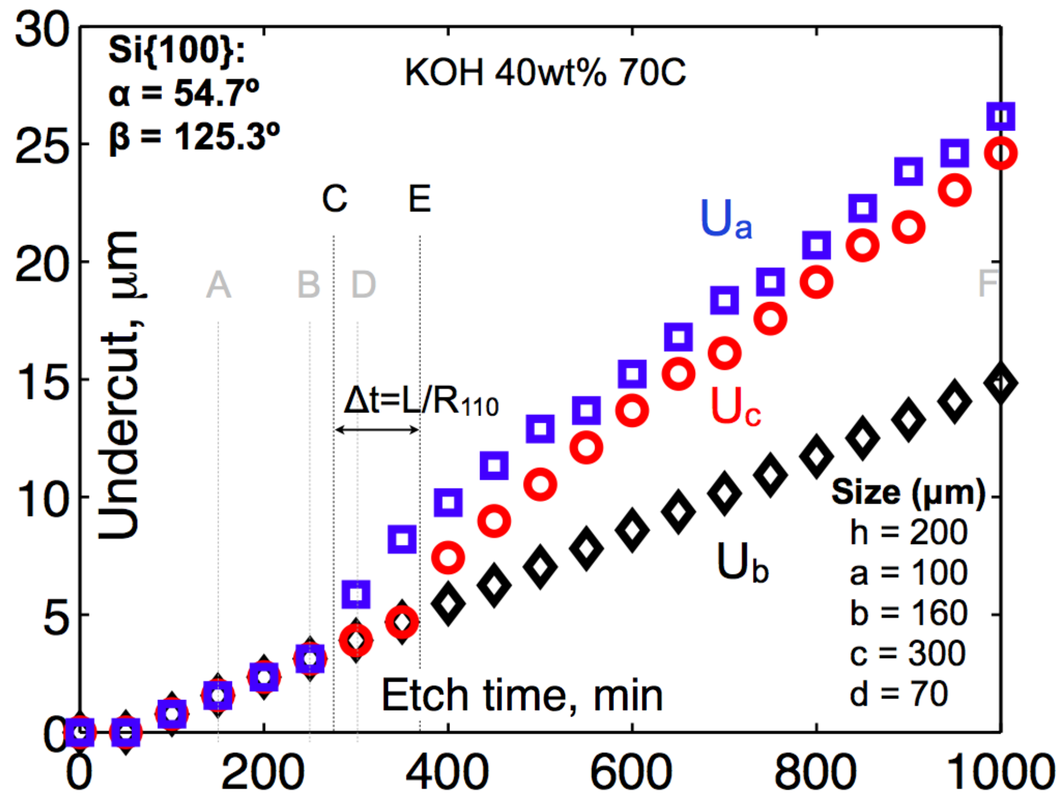
This is due to a faster removal of the substrate atoms located at the mask-substrate interface (such as S and S'), as compared to those located away from the interface. In fact, interface atoms with smaller coordination number (less neighbors, such as S′) have larger removal rates.

Due to the atomistic nature of **IntelliEtch**, these effects are easily incorporated. Frame (a) shows the shape of an etched cavity on Si(137) when all (111) facets have the same etch rate (traditional simulators). By adjusting the etch rates of the interface atoms the simulated shape by **IntelliEtch** (b) matches the experiment (c). The simulator can then predict other structures.

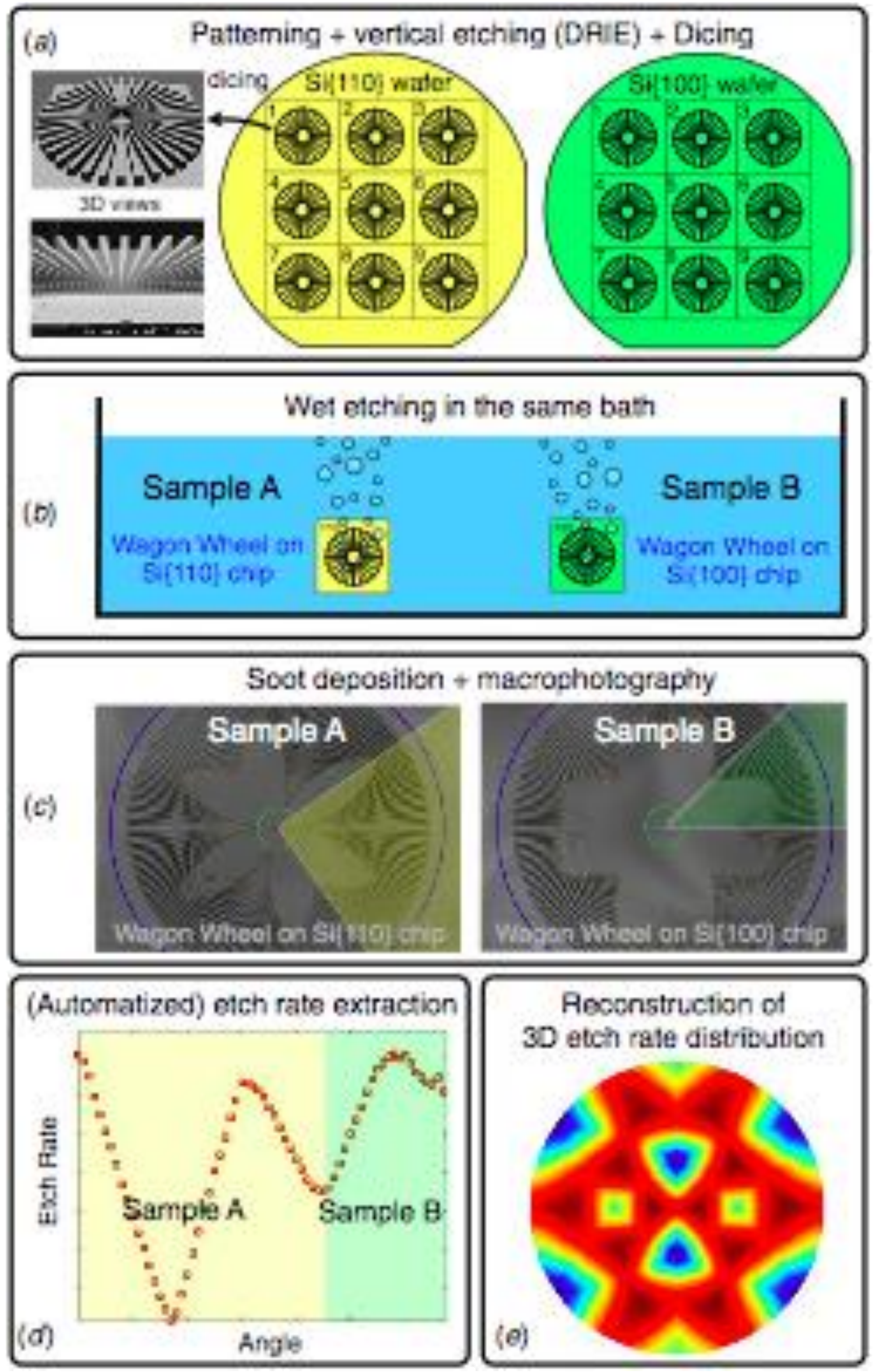




Due to this feature **IntelliEtch** can simulate wafer perforation phenomena with unprecedented detail. Where traditional simulators yield the same behavior for undercuts U_a, U_b and U_c (all falling on the black diamond line for U_b) **IntelliEtch** describes how U_a and U_c become larger than U_b after certain events during the time evolution.

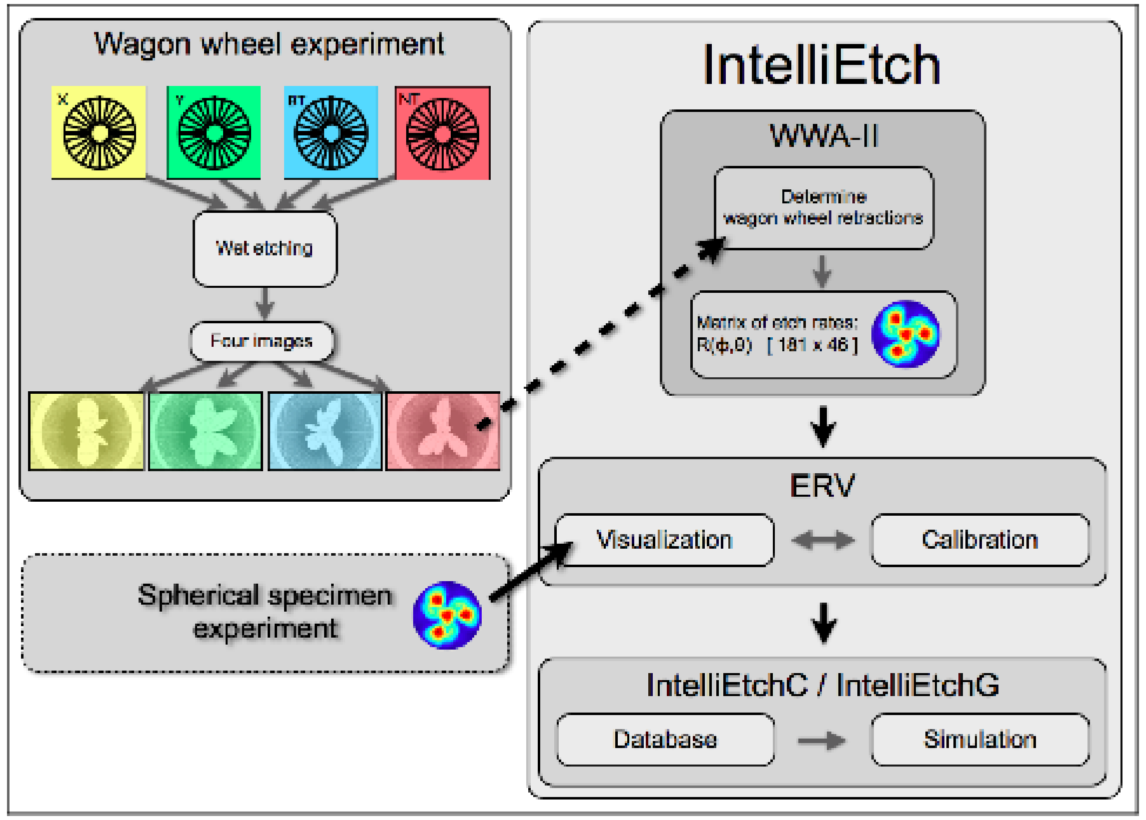


7. Characterize your etchant to understand how it etches

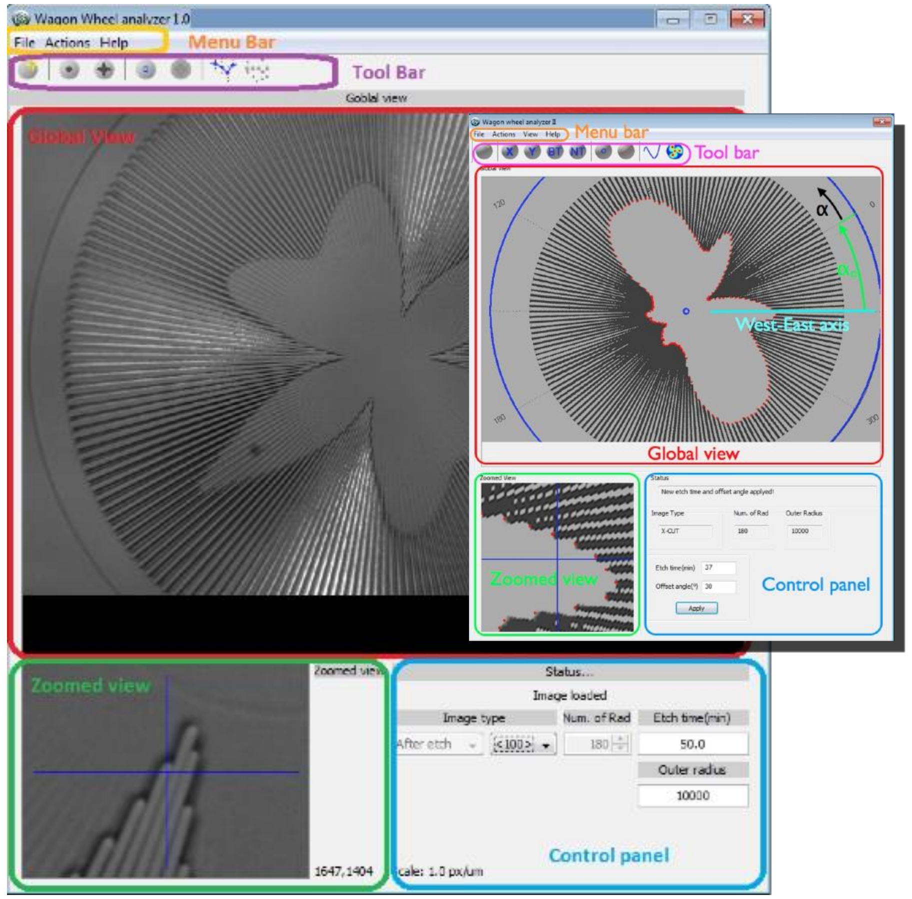


The **Wagon Wheel Analyzer (WWA)** and **Etch Rate Visualizer (ERV)** are part of **IntelliEtch**.

The WWA is used to extract the key etch rates of your etchant. Simply use DRIE, vertically-micromachined silicon or quartz wagon wheels (a), etch them in your solution (b), take a picture (c), and use the WWA to automatically extract the etch rates. The ERV uses those rates to generate the complete orientation-dependence of your etchant (d), as well as to calibrate **IntelliEtch**'s simulation engine in order to perform fast, realistic simulations with it.



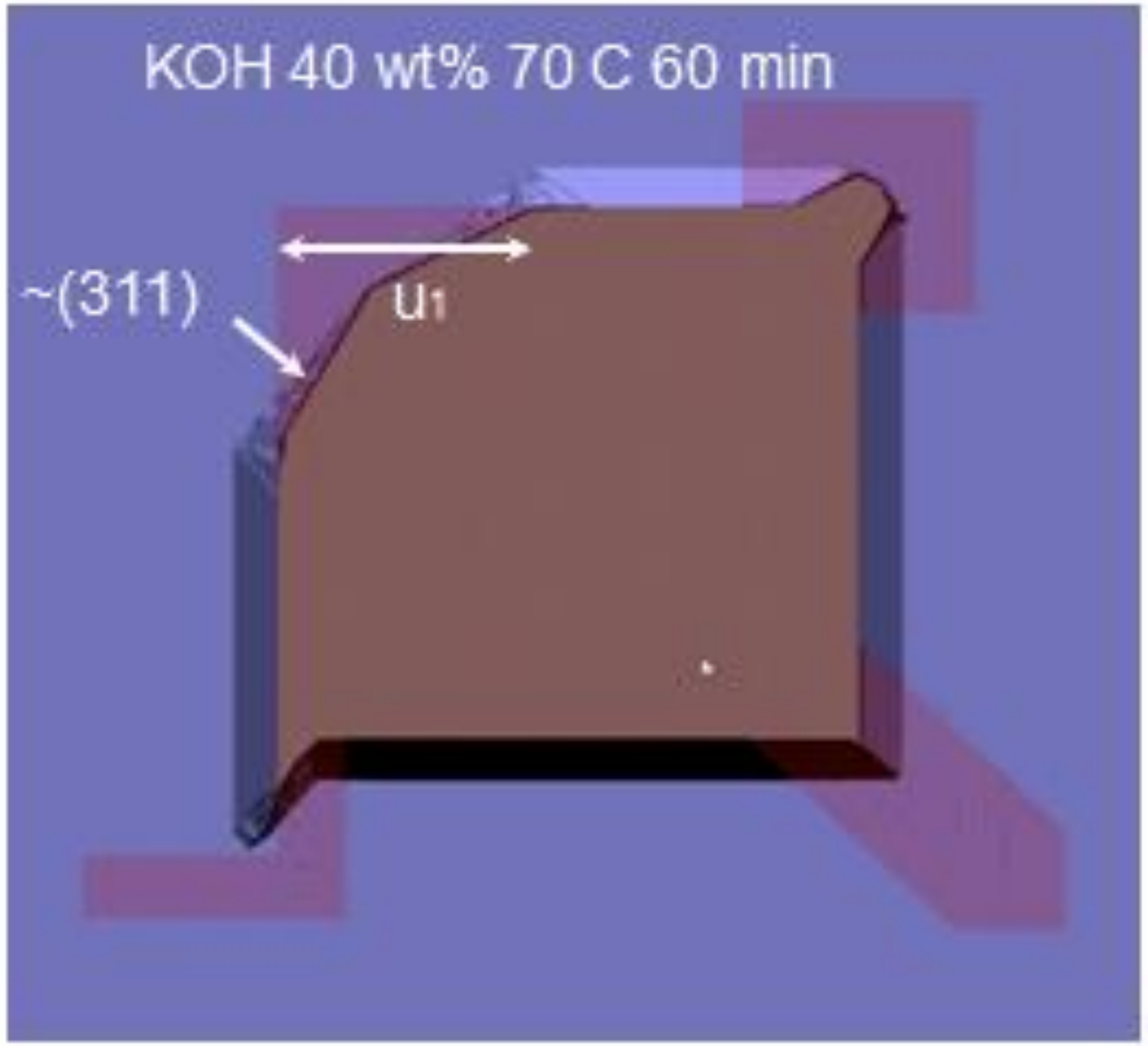
Use the WWA to extract etch rates for silicon (left figure) or quartz (top). The ERV accepts input from the WWA, but also from hemisphere etching experiments.

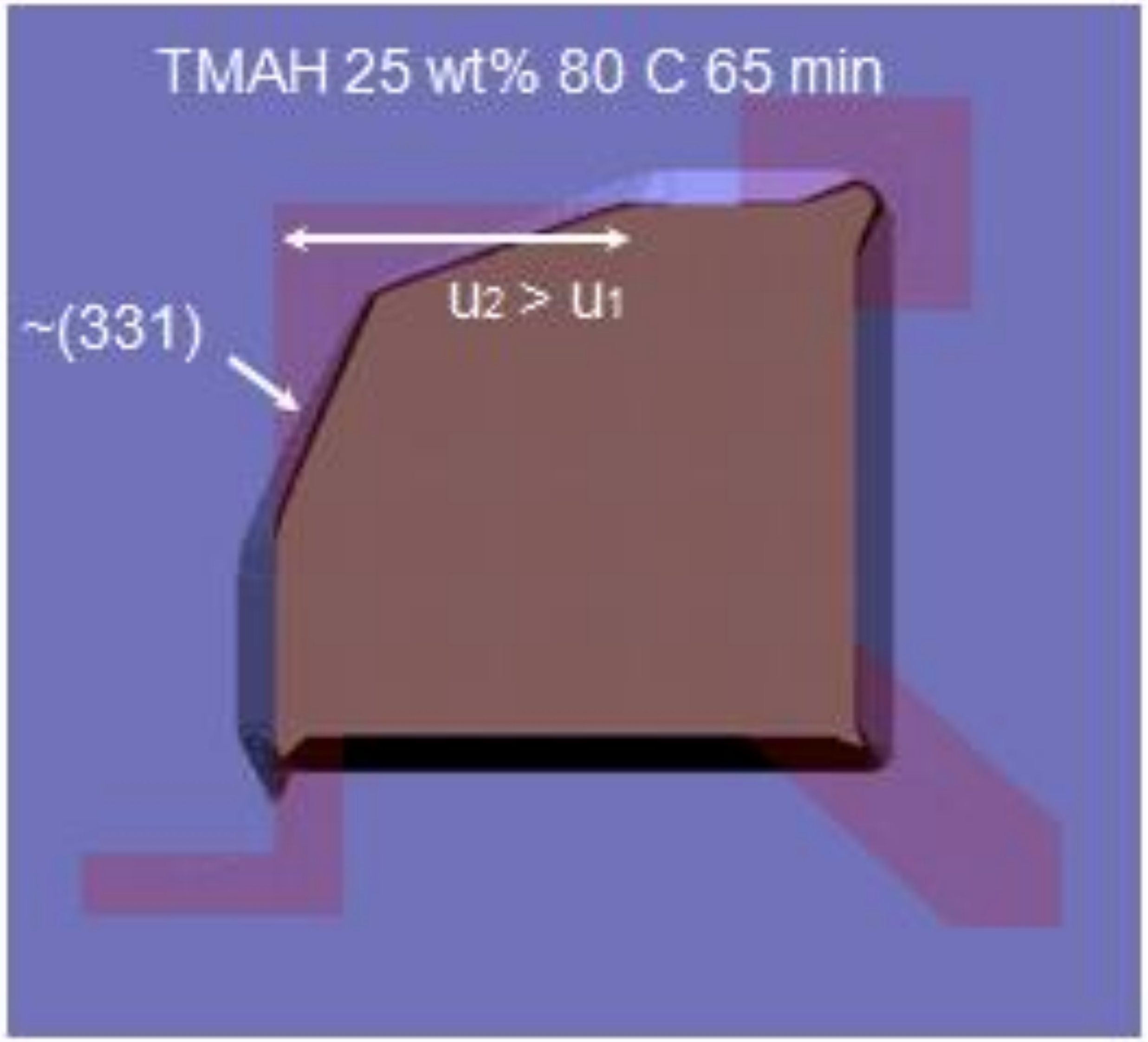


Main frame: WWA-I for silicon
Inset: WWA-II for quartz

8. Convex corner undercutting and compensation

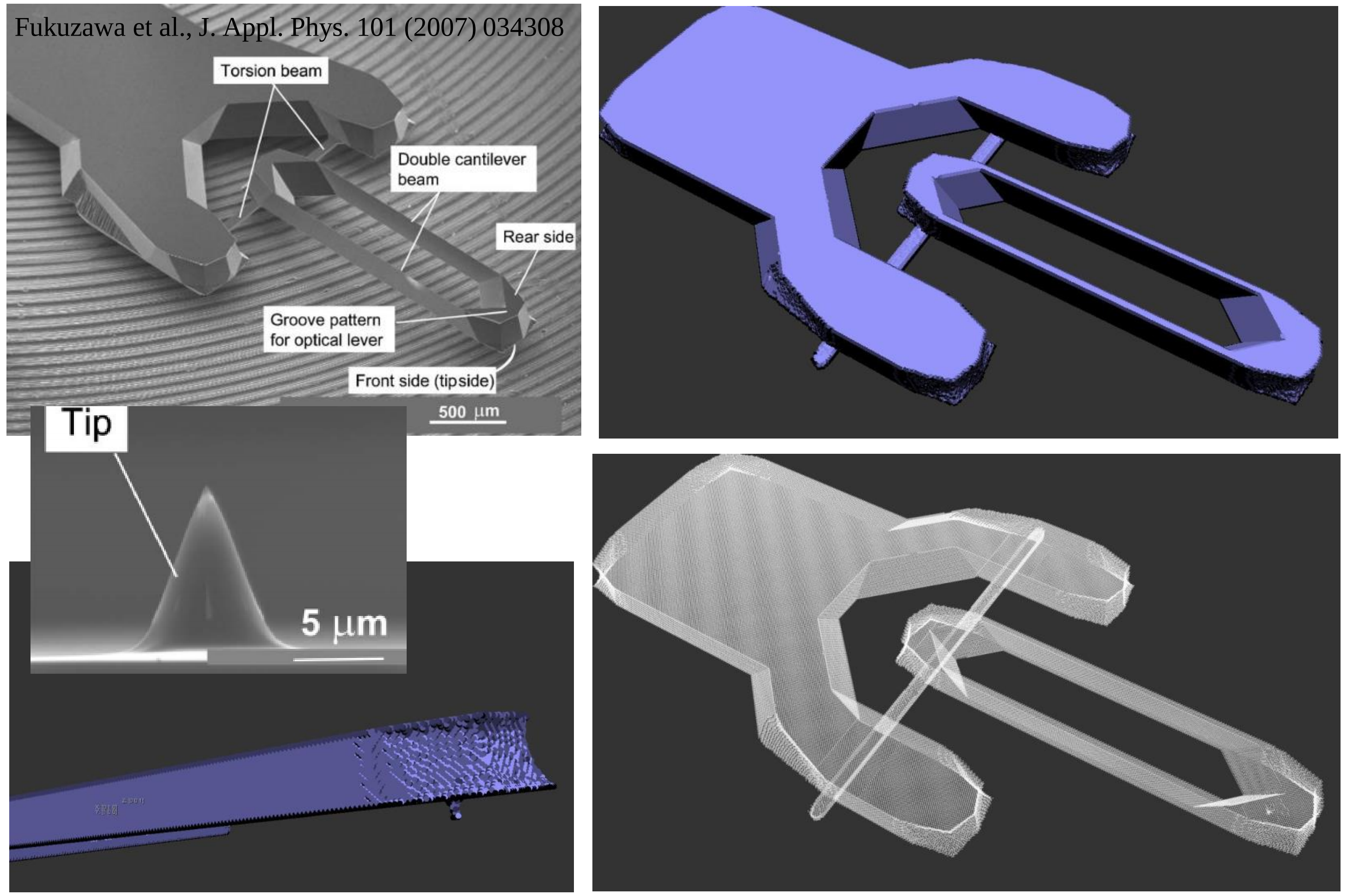
The shape of the etch front during convex corner undercutting of silicon depends strongly on the chosen etchant. In a first approximation, knowledge of the etch rates of (100), (110), (111) and (311) or (411) is enough to describe the shapes for KOH 30-40 wt%. However, if the etchant is different from KOH, the simulations must incorporate other etch rates. For instance, TMAH 10-25 wt% requires the use of at least (100), (110), (111) and (331) or (441), while TMAH+Triton requires the complete orientation-dependence of the etch rate on the unit sphere. **IntelliEtch** has the ability to use different etch rates and/or the complete rate distribution for any etchant.

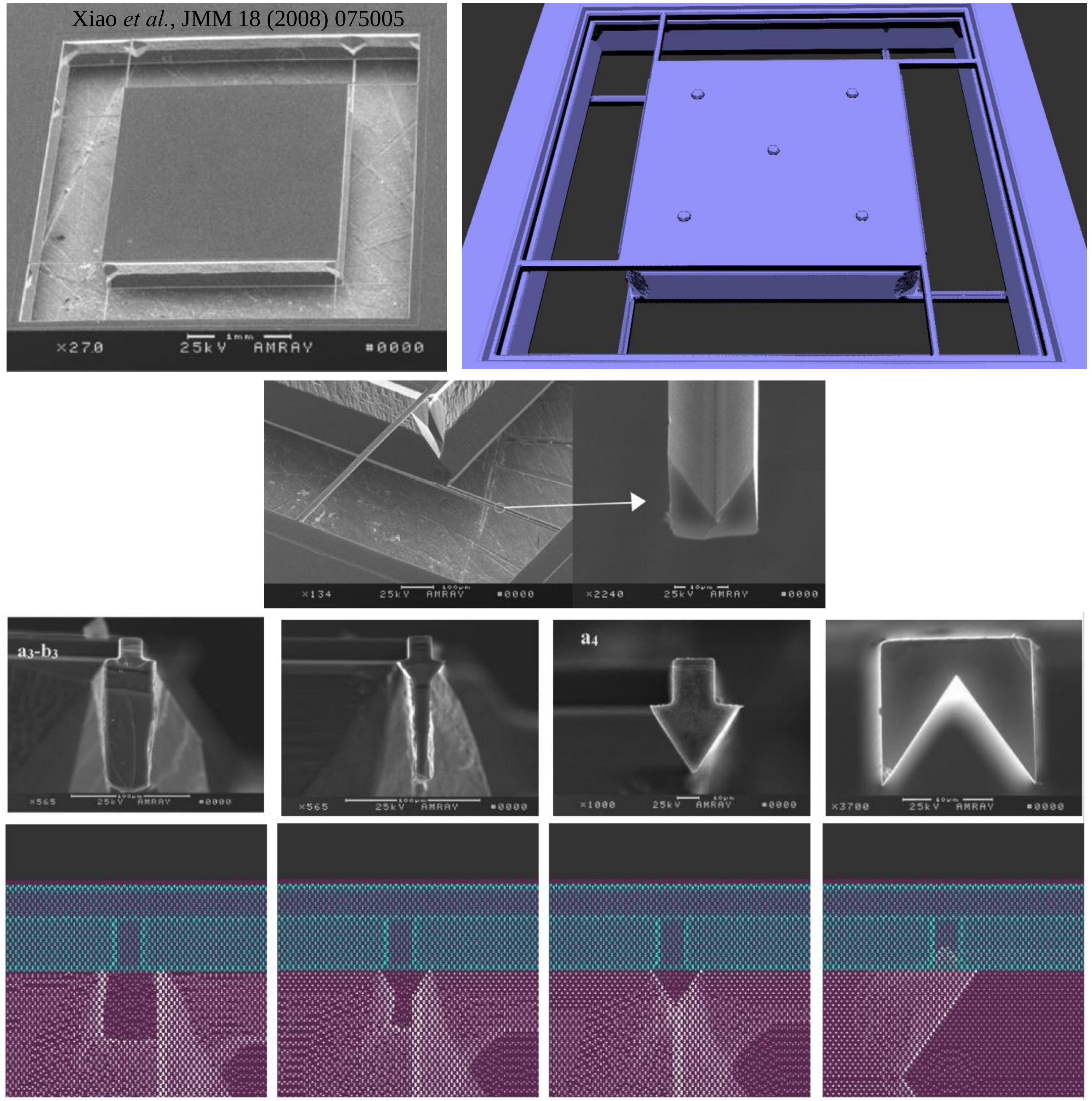




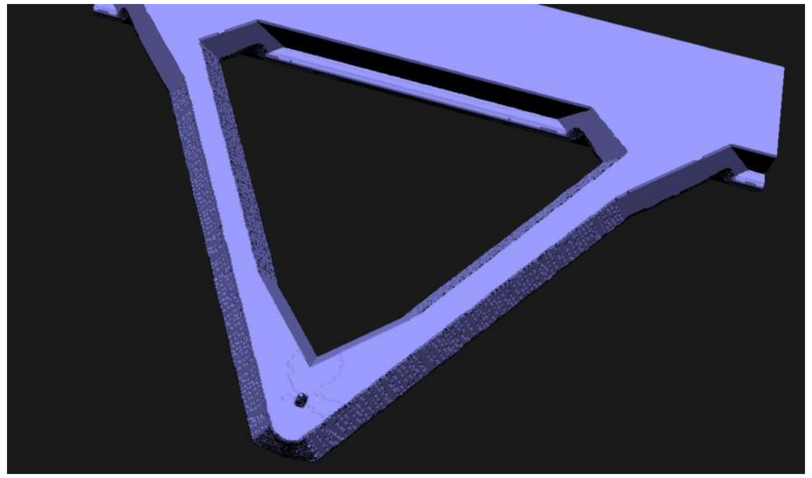
9. Complex processing with multiple etching steps: (A) KOH

Comparison of experiment and simulation by **IntelliEtch** for double-side, multiple etching in KOH

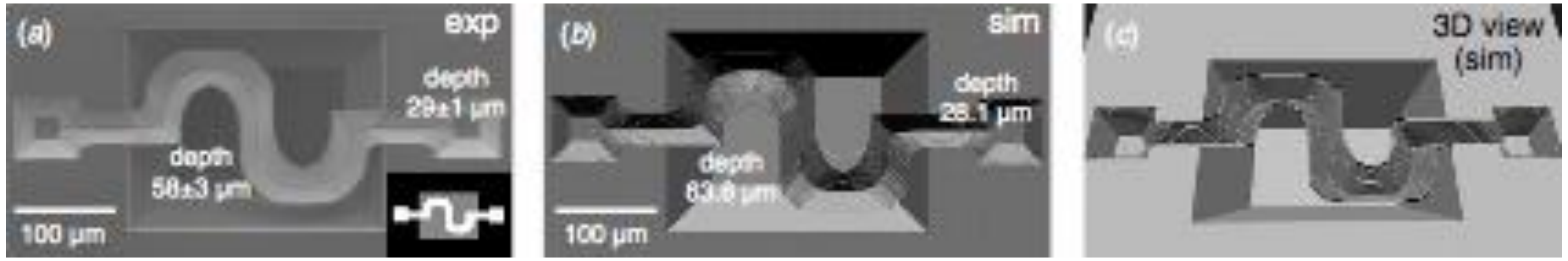




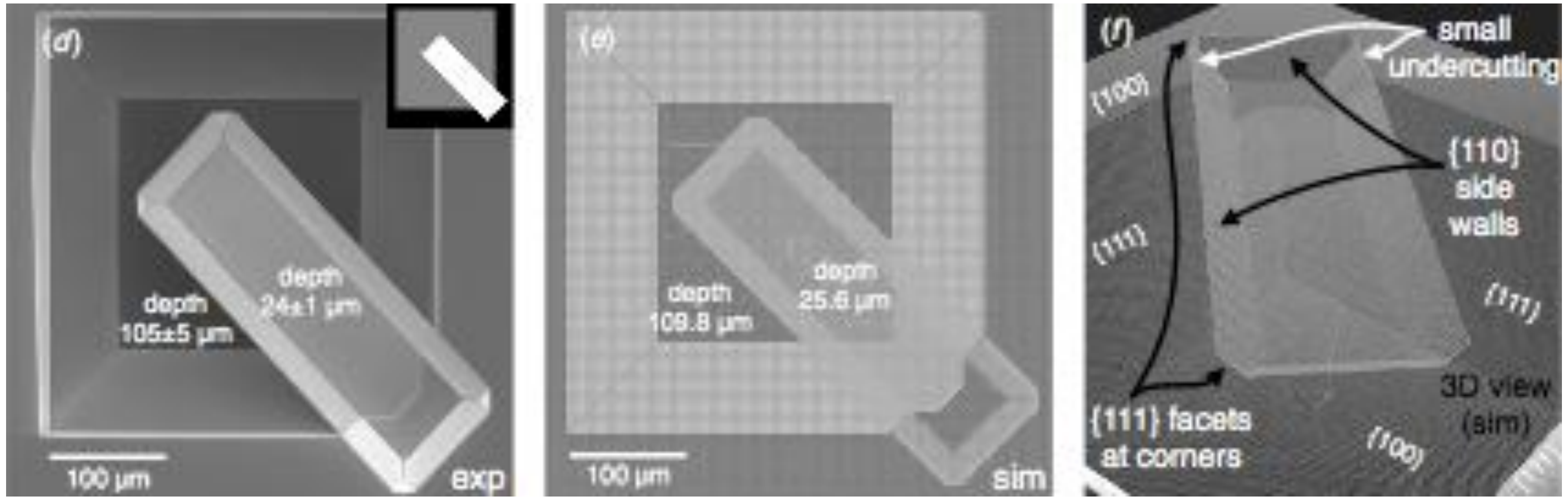
C. Liu, Foundations of MEMS, Pearson Prentice Hall, ISBN 0-13-147286-0,(Fig. 10-3-1)



9. Complex processing with multiple etching steps: (B) TMAH and TMAH+Triton

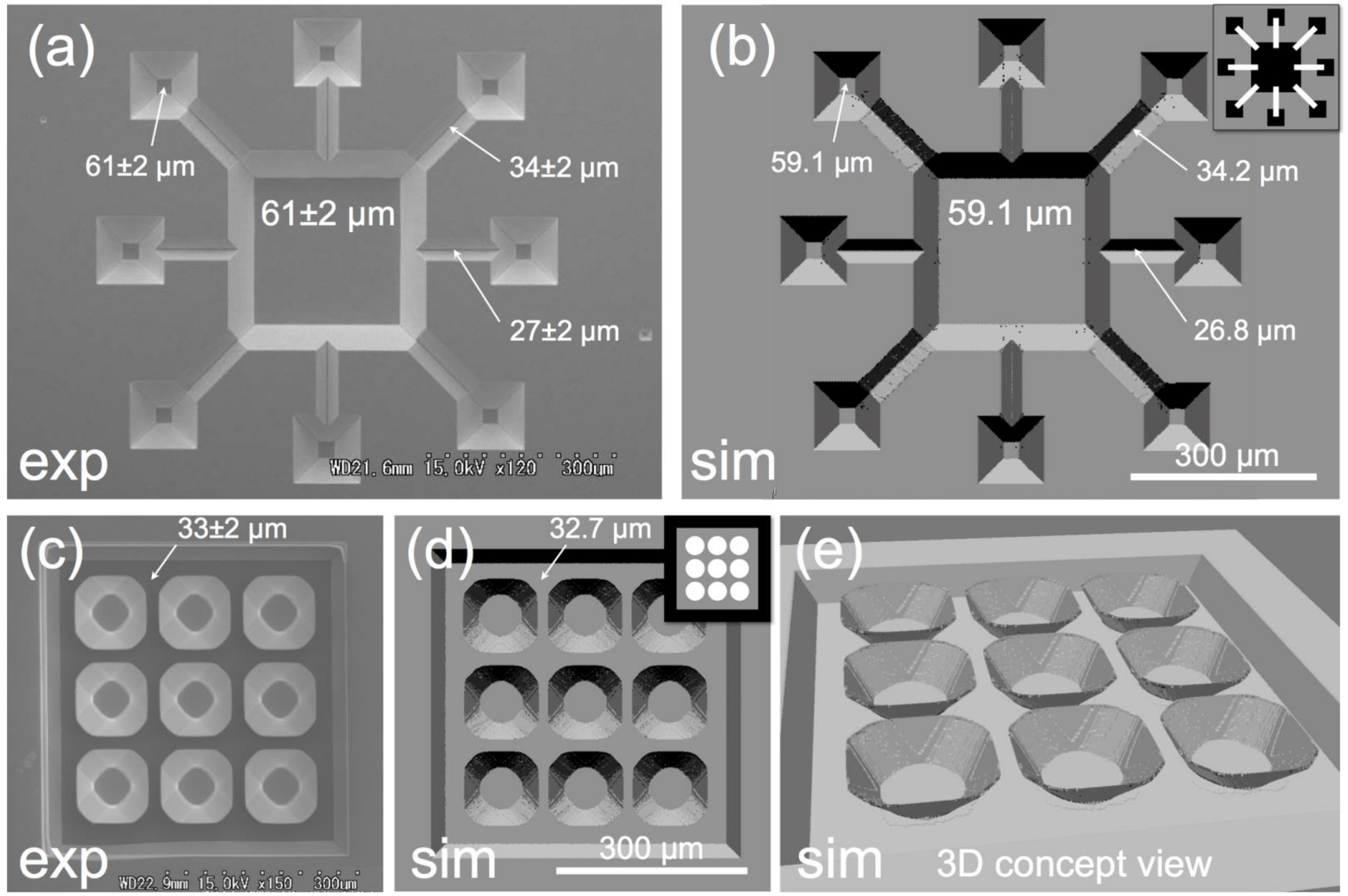


(a) Experimental image of a suspended serpentine microchannel. (b) Simulation by **IntelliEtch**. (c) 3D view of the simulation.



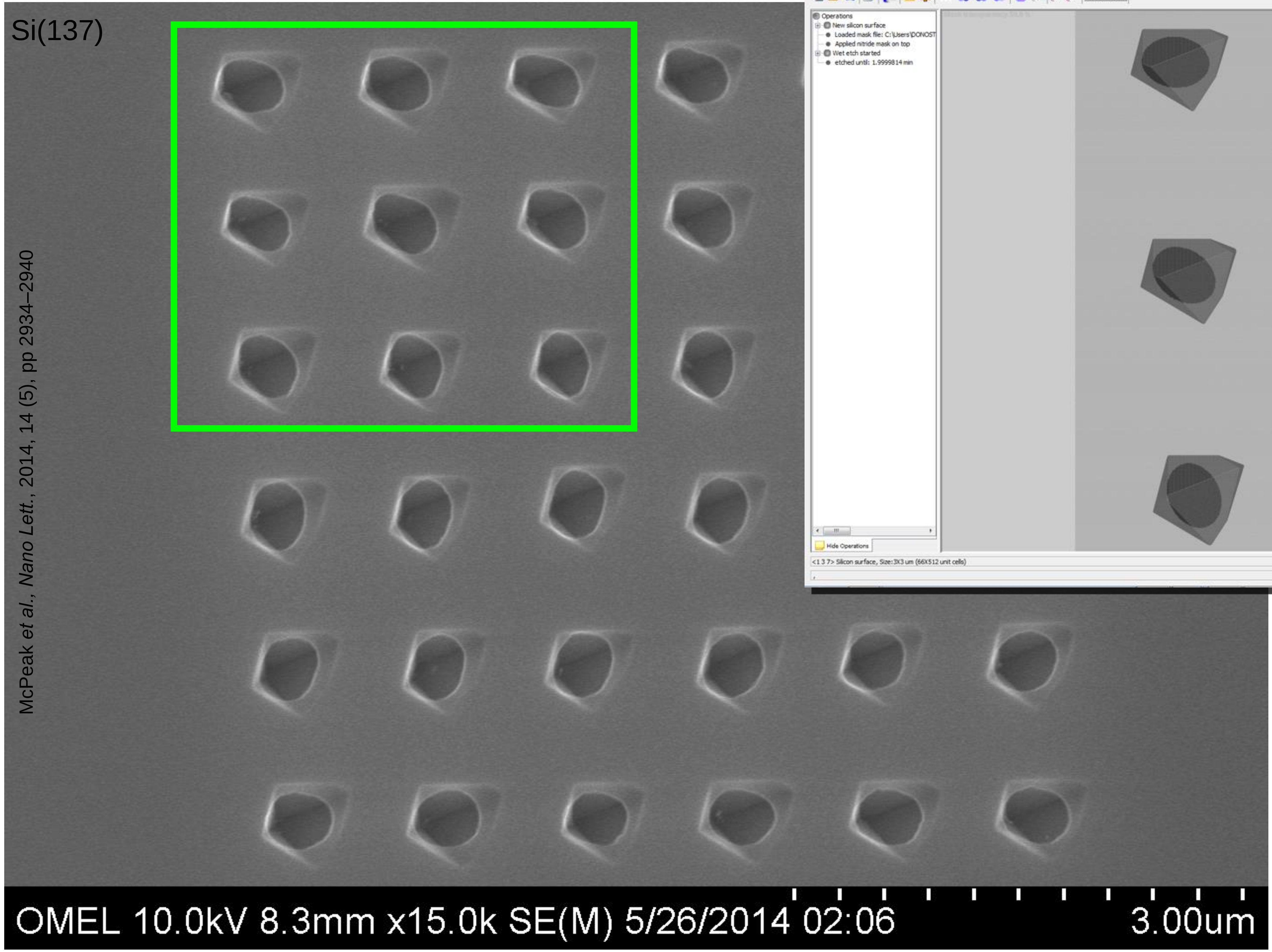
(d) Experimental image of a diagonal tray-shaped cantilever with {1 1 0} sidewalls (L = 350 µm, W = 100 µm). (e) Simulation by **IntelliEtch**. (f) 3D view of the simulation.

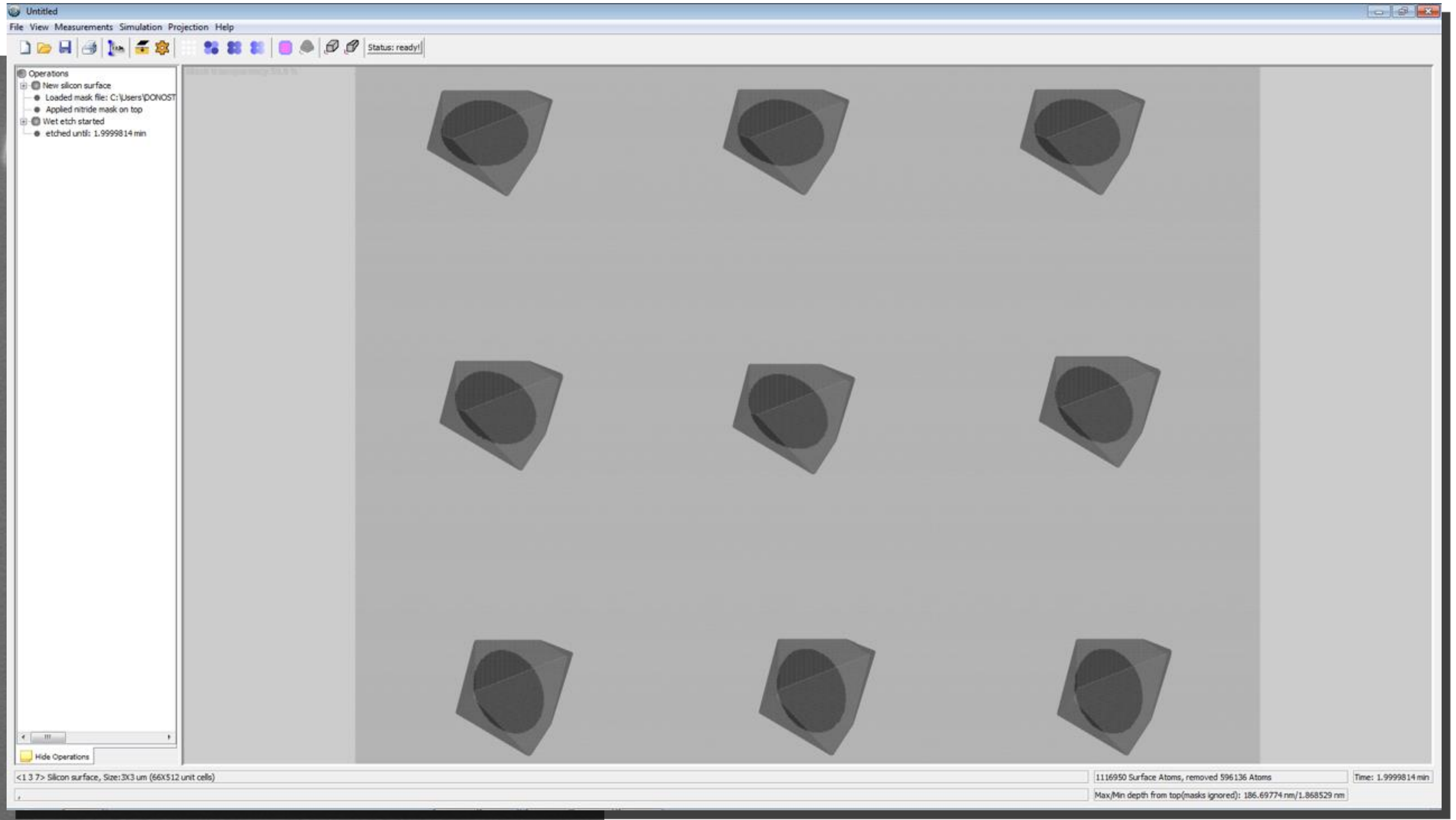
Comparison of experiment and simulation by **IntelliEtch** for multiple etching in TMAH + Triton and TMAH for the creation of (a)–(b) microchannels and reservoirs on silicon; (c)–(e) rounded bucket array using silicon dioxide. Mask patterns: black = oxide, gray = nitride, white = bare silicon.



Processing steps (T = 80 C):
(1) Nitride patterning, (e) etching in TMAH 25 wt% + Triton 0.1 vol%, (3) oxide growth on bare silicon, (4) nitride removal, (5) etching in TMAH 25 wt%

10. Submicron, nanoscale etching



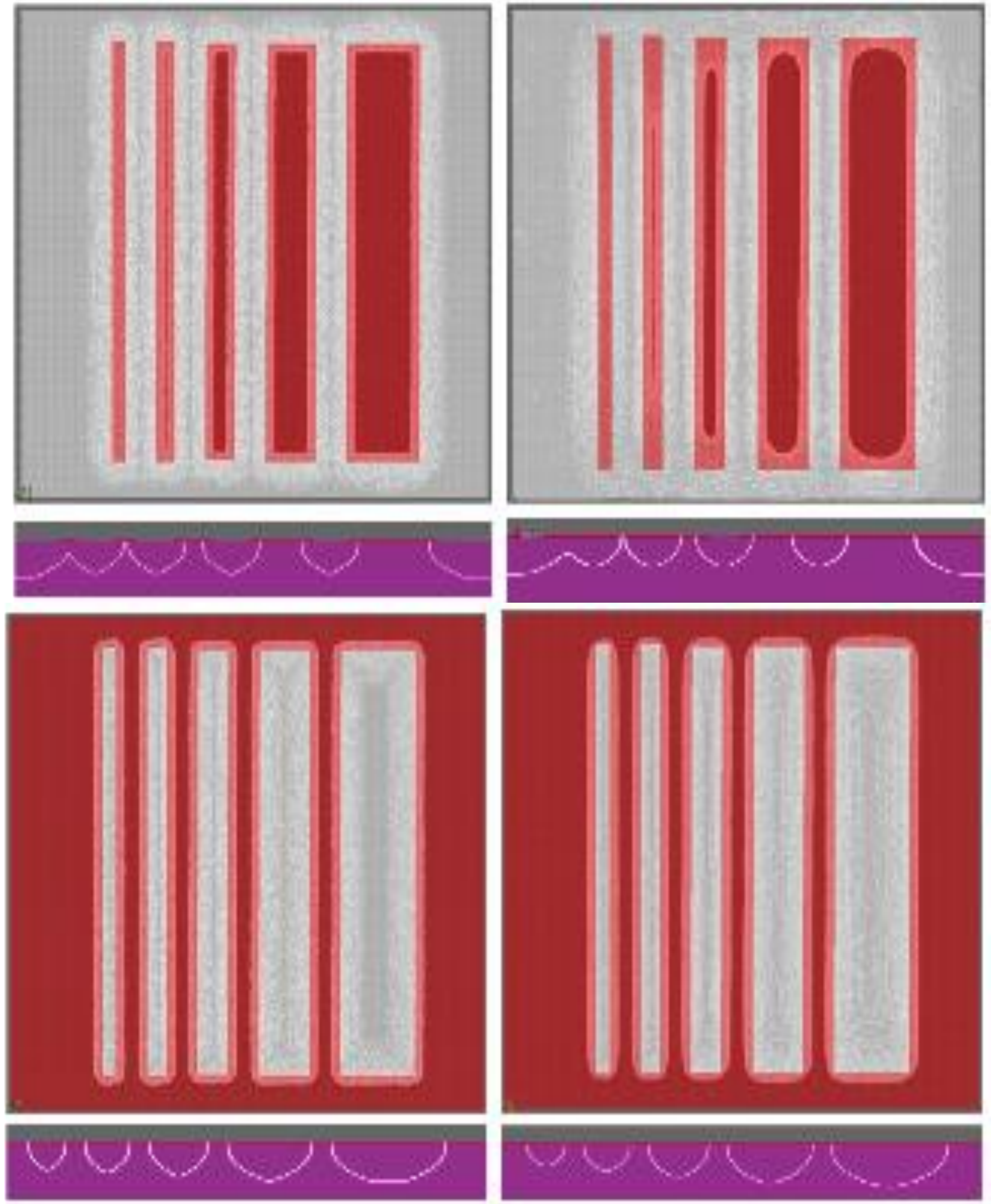


IntelliEtch has been validated for the simulation of submicron nanocavities in order to generate chiral surfaces and nanoparticles.

11. Diffusion-limited isotropic etching

Isotropic etching...

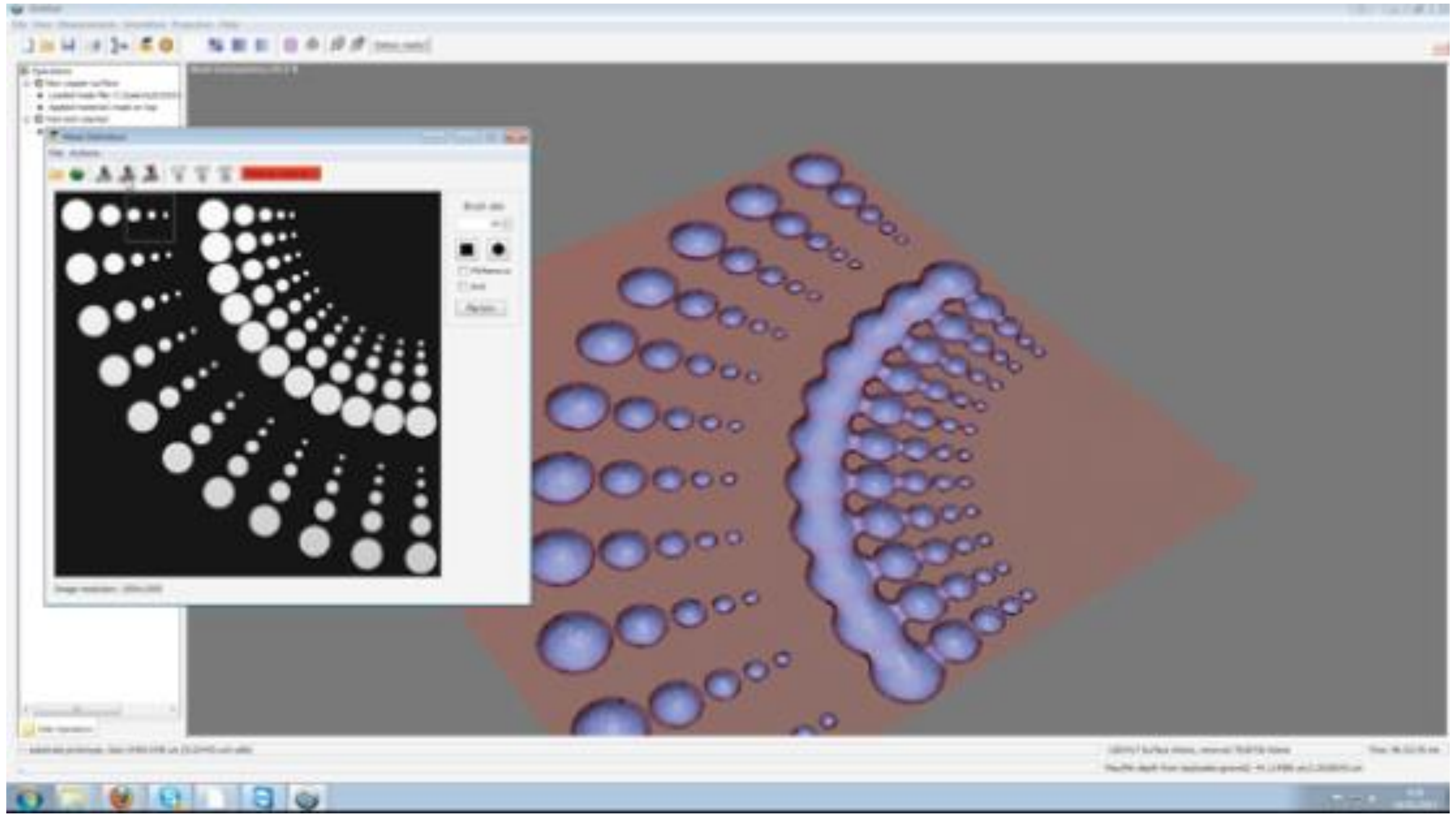
...without diffusion effects ...with diffusion effects



IntelliEtch-Iso (also known as **IntelliEtch-Metal** and **IntelliEtchSpray)** is part of **IntelliEtch.** **IntelliEtch-Iso** is suitable for the simulation of isotropic etching of semiconductors (silicon, GaAs,...), spray/wet etching of metals (Cu, Cu alloys,...) and, in general, of any material. It is used by IC engineers to design the mask pattern for a target shape of the metal interconnects.

IntelliEtch-Iso provides a deeper understanding of the diffusion effects through the correlation to the local curvature of the front, which leads to increased undercutting at convex geometries and larger etch depths at wide openings.

IntelliEtch-Iso can be calibrated to describe a specific substrate + etchant. Simply perform an etching experiment with a specific mask, generate several cross-sections of the etch results and take a few pictures. Once calibrated, **IntelliEtch-Iso** can be used to simulate etching for any mask pattern.



12. Up to three cross-sections with geometrical measurements

IntelliEtch allows the definition and display of up to three cross sections for the currently visualized system: two vertical and one horizontal. A vertical cross section looks as a line when observed from the Z axis and can be defined by the XY coordinates of two points, either by manual input or by selecting the two points using the mouse. Distances, angles and Miller indices can be measured on the cross-sections and 3D views. The colors of all objects are controlled by the user.