

SiO₂ Etch using Ru Hardmask

Credit: Initial Ru/SiO₂ etch processes developed by **Bill Mitchell**, Ph.D. (using ALD+EBL).

Transferred to Sputter Ru/I-line Stepper by **Ning Cao**, Ph.D.

Please consider adding the appropriate co-authors if you publish work using this process as your starting point.

June 25, 2019, Ning Cao

Goals

- Vertical SiO₂ etching in Fluorine ICP Etcher
- High selectivity Ruthenium (Ru) hard mask
 - Deposit by AJA Sputter
 - Etched in O₂/Cl₂ (Panasonic ICP)
- Pattern with Standard I-Line Stepper PR and Lithography
 - Photoresist: SPR 955-0.9
 - GCA Autostep 200

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Procedure

Substrate

- Prime Grade silicon
- Wet Thermal SiO₂ ≈ 5μm.
- (Sample Name: Ru#20-02)

Ru Film Deposition using Sputter#4

Tool: AJA Sputter #4

- Recipe Name: ***Ru-Dep-Ning Load*** (Staff login “Password1” – make a copy)
- Recipe Parameters:
 - 3mT,
 - 200W (~456v),
 - Ar Flow-rate=45 sccm,
 - Tilt/z = 4mm / 2.75 inch
 - Rotation=10 rpm,
- Ru Deposition Rate: ~10nm/min
- Deposited ~150nm of Ru

Photolithography

1. *Optional*: Solvent clean: acetone (2') + iso-propanol (1') in ultrasonic bath (HF) DI rinse and Dry in dryer
2. Bake at 135°C, 5 min (cooling on metal surface for 1 min)
3. Technics PEII: O2 descum, 300mT/100W, 1 min
4. Spin-on HMDS: 3500rpm, 30 sec (waiting for 20 sec before spinning)
5. Spin-on SPR955-0.9 resist: 3500 rpm, 30 sec
6. Bake at 95°C for 60 sec
7. Exposure:
 - a. Log in [10,1]
 - b. CHUCK to select 100mm wafer chuck
 - c. SETUP the tool
 - d. RMSL to load reticle
 - e. Load the wafer onto 100mm chuck (no shims on the back!);
 - f. EDIT NiNG1:
 - i. Exposure = 0.39 sec,
 - ii. FO=3,
 - iii. Alignment Mark Phase: N,
 - iv. the distance between lens and wafer surface should be within -6 to 6 V (mask: linedotresistcal: 4x4 cm² pattern)
 - g. Perform the exposure
 - h. RMSR to retreat reticle

- i. RMSL to remove the reticle
8. PEB at 110°C for 60 sec
9. Develop in AZ300MIF for 60 sec
10. Technics PEII: 300mT/100W 45 sec
11. Measure Photoresist on Tencor P-7: 0.80049 μm resist thickness

Ruthenium Etch Procedure

Tool: Panasonic ICP #1

Optional: Intellemetrics Laser Monitor

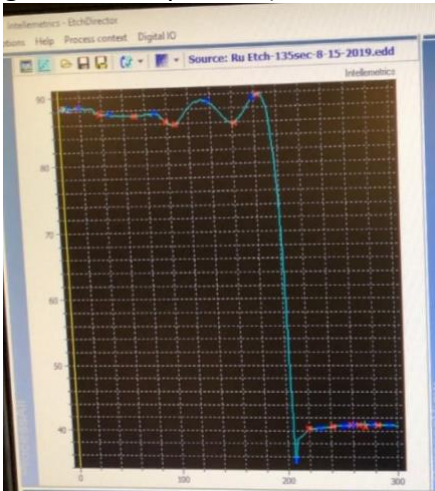
(Cleaved 100mm wafer into quarters)

Mount $\frac{1}{4}$ of 100mm wafer with oil

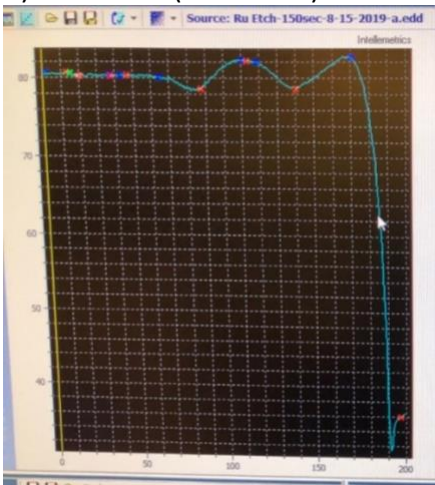
Bill's Ru Etch Recipe: 2.5Pa, 50/500W, Cl₂=5.5sccm, O₂=49.5 sccm

Etch time: determined by laser monitor. 135sec until Ru was etched.

a) Quarter A (major flat) : Etch Time=135sec (Stop etching when the laser monitor curve goes from dip to flat)

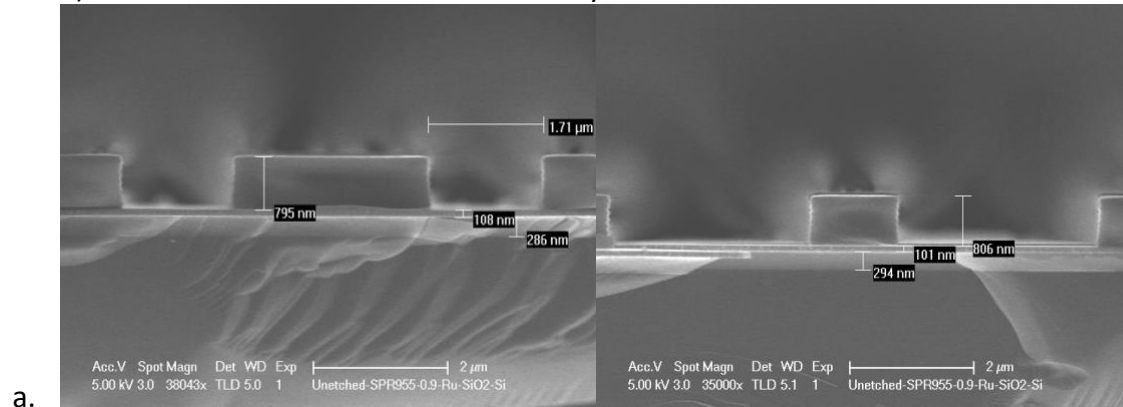


b) Quarter B (minor flat): Etch Time=150 sec (a little bit over etched)

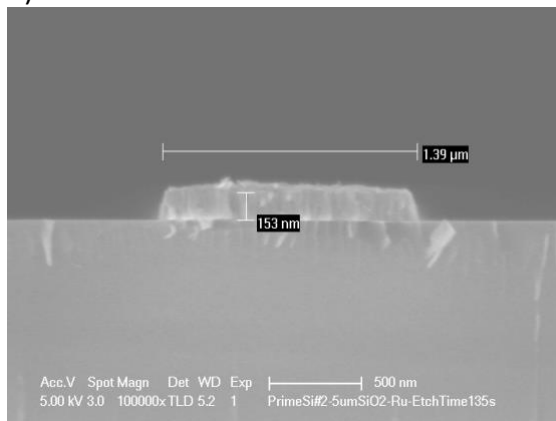


Ru etch profile (SEM)

a) Resist Etch Mask Profile before Ru dry etch



b) Ru Mask: etch Profile



SiO₂ Etch with Varying Bias

50W Bias SiO₂ Etch using Ru etch mask

SiO₂ Etch Procedure

Tool: Plasmatherm SLR Fluorine ICP

Note: Remaining Photoresist mask is left intact. Could optionally remove with O₂ etch.

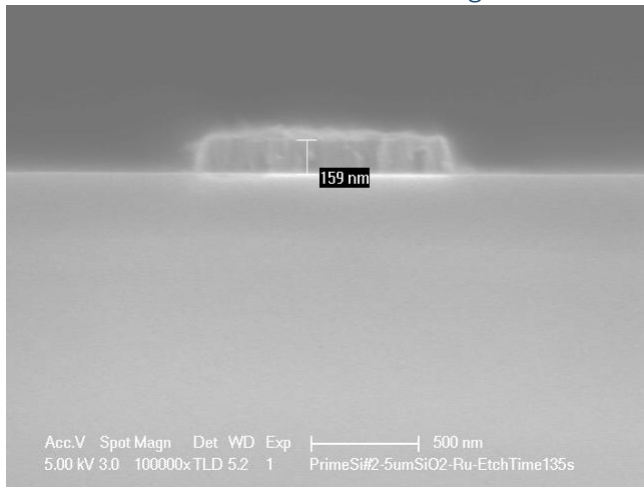
1. O₂ clean chamber (O₂ Clean-Useme-STDRCP), cleaning wafer
 - a. 5mT, O₂=100sccm, 10/850W, and time=30min
2. Chamber coating (carrier only): 30 sec of same recipe as below
3. Real samples (~1x1 cm²) etch run (2 samples: one with Ru etch mask, the other with PR mask)
 - a. SiO₂ Recipe: CHF₃/CF₄/SiO₂ Etch-cao
 - b. 3.8mT, RF/ICP = 50/800W, CF₄=30, CHF₃=10 sccm, and time=5 min
4. O₂ chamber clean after etch (cleaning wafer): 10 min

50W Bias Results

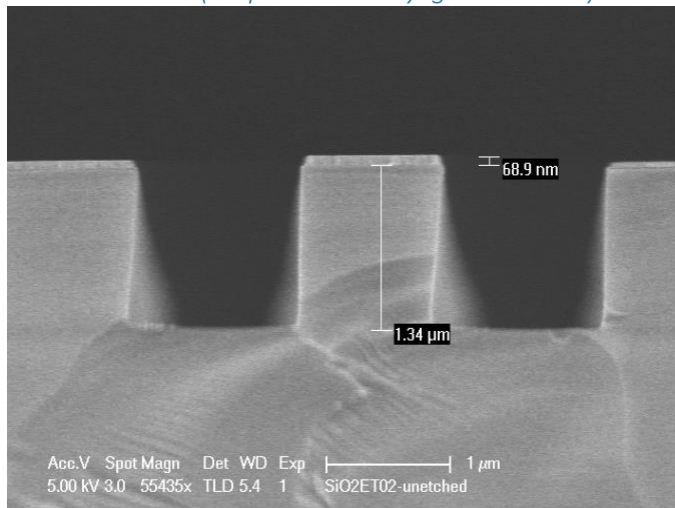
Average SiO₂ Etch rate=0.263 $\mu\text{m}/\text{min}$,
Etch Selectivity=36.4

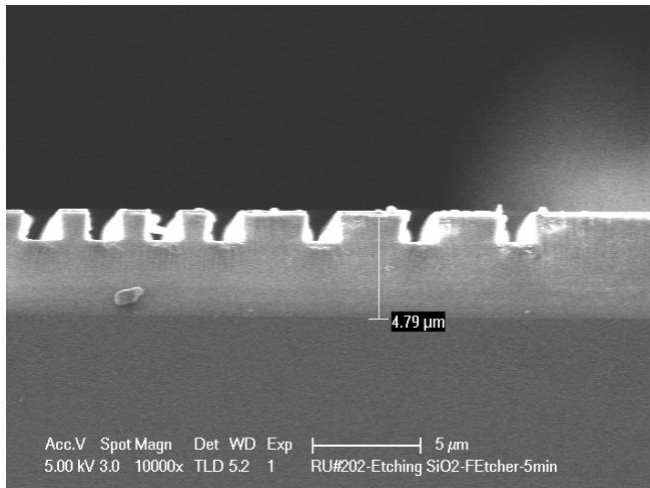
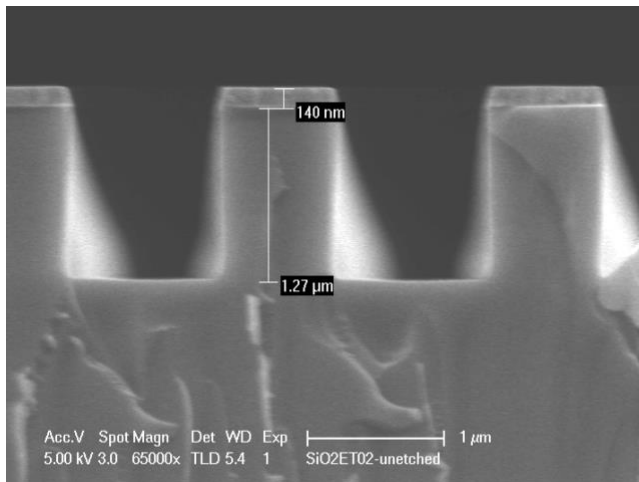
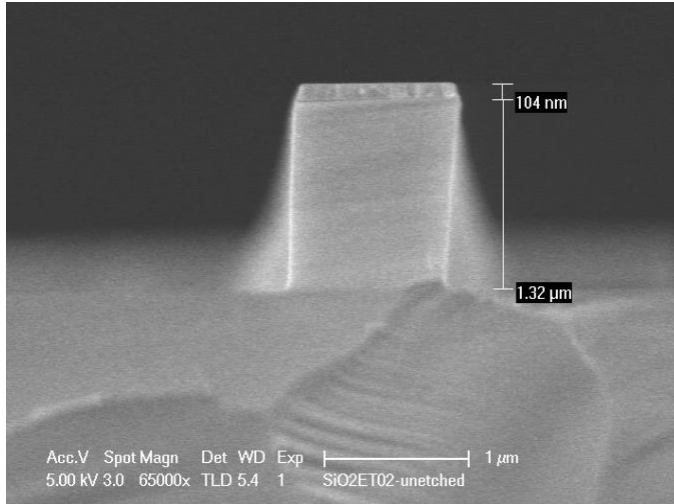
50W Bias SEMs

Ru Etch Mask Profile before SiO₂ etching

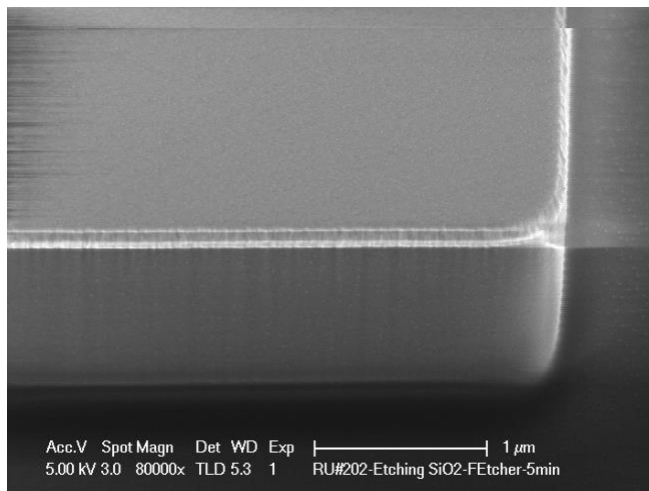
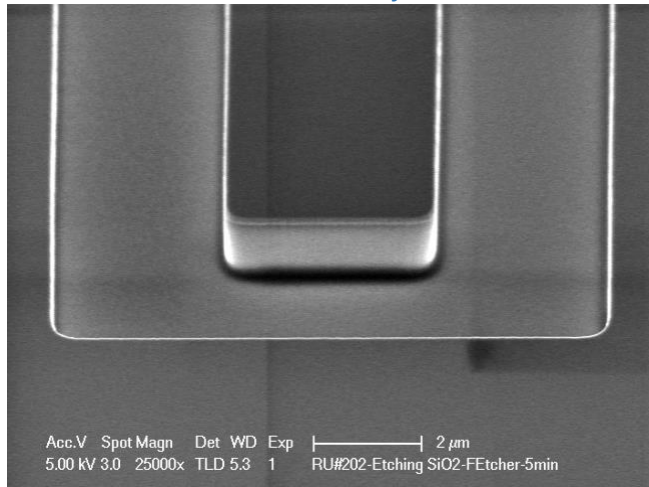


50W Bias SiO₂ (~5 μm thermally-grown oxide) Etch Profile





50W Bias Etched Side-wall Profile



200W Bias SiO₂ Etch using Ru etch mask

Sample: Ru#20-03 (1-22-2020)

SiO₂ Etch Procedure

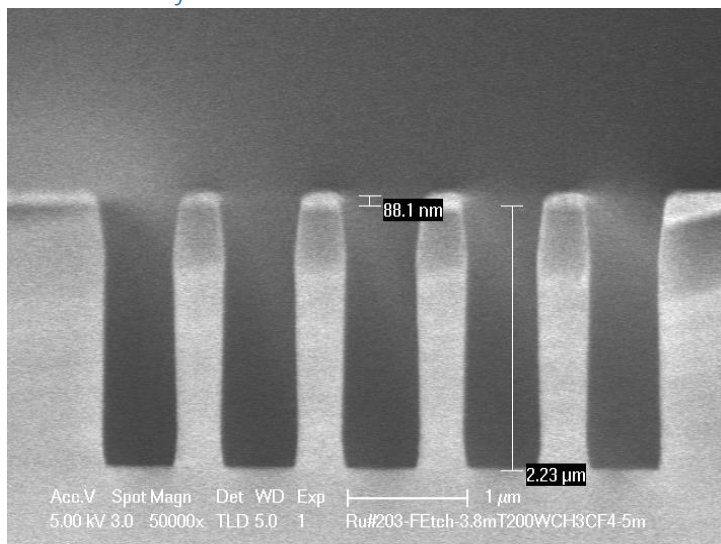
- 1) O₂ clean chamber (O₂ Clean-Useme-STDRCF) 5mT, O₂=100sccm, 10/850W, and time=20min
- 2) Chamber coating (carrier only): 30 sec
- 3) Real samples (~1x1 cm²) etch run
Recipe: CHF₃/CF₄/SiO₂ Etch-cao
3.8mT, RF/ICP = **200**/800W, CF₄/CHF₃=30/10 sccm, and time=5 min
- 4) O₂ chamber clean after etch: 10 min

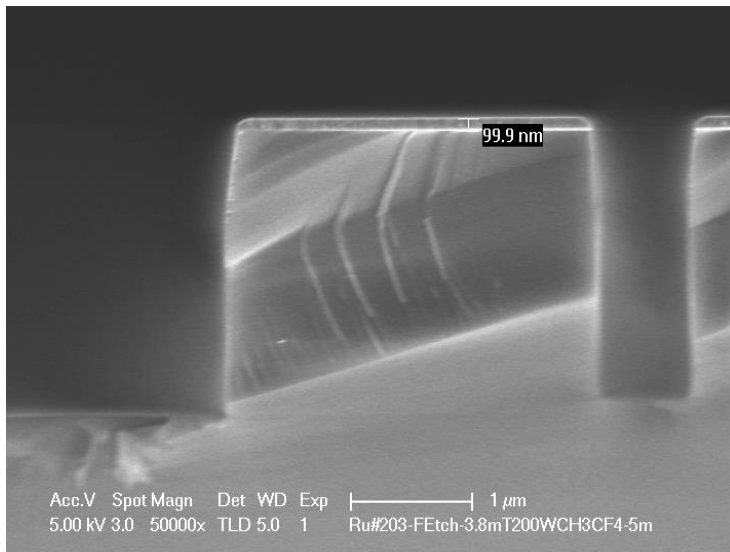
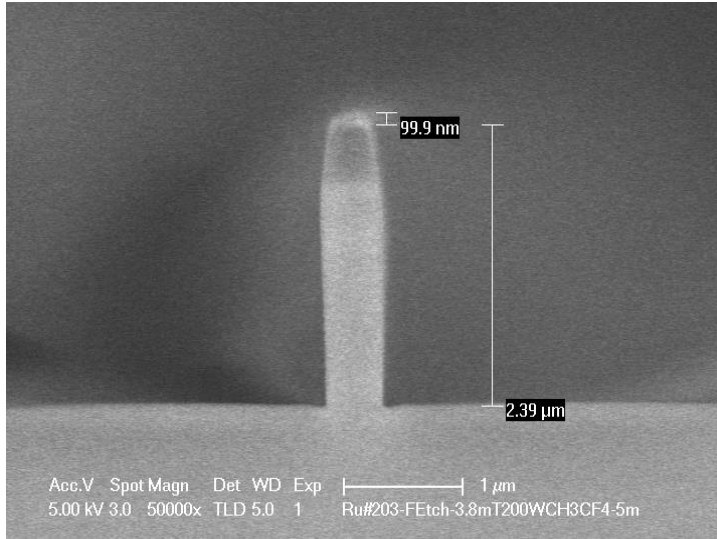
200W Bias Results

Average SiO₂ Etch rate=0.471 $\mu\text{m}/\text{min}$,
Etch Selectivity=37.7

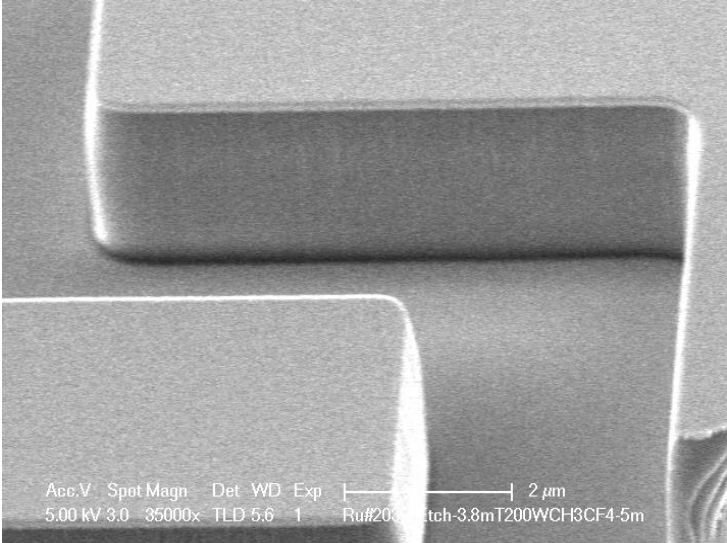
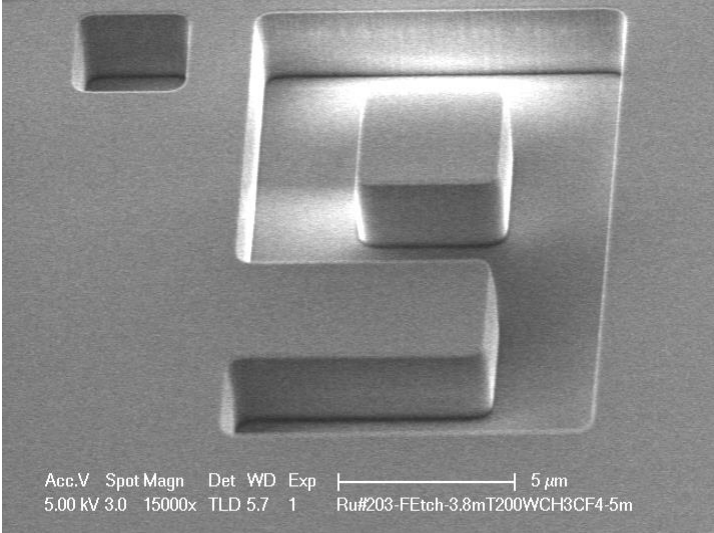
200W Bias SEMs

SiO₂ Etch Profile





Etched Side-wall Profile



400W Bias: SiO₂ Etch using Ru etch mask

Sample: Ru#20-04 (2-11-2020)

SiO₂ Etch Procedure:

Tool: Plasmatherm SLR Fluorine ICP

1) O₂ clean chamber (O₂ Clean-Useme-STDRCP) 5mT, O₂=100sccm, 10/850W, and time=30min

2) Chamber coating (carrier only): 30 sec

3) Real samples (~1x1 cm²) etch run

Recipe: CHF₃/CF₄/SiO₂ Etch-cao

3.8mT, RF/ICP = **400**/800W, CF₄/CHF₃=30/10 sccm, and time=2.5 min (150 sec)

- (Bias Voltage=390-410V)

4) O₂ chamber clean after etch: 15 min

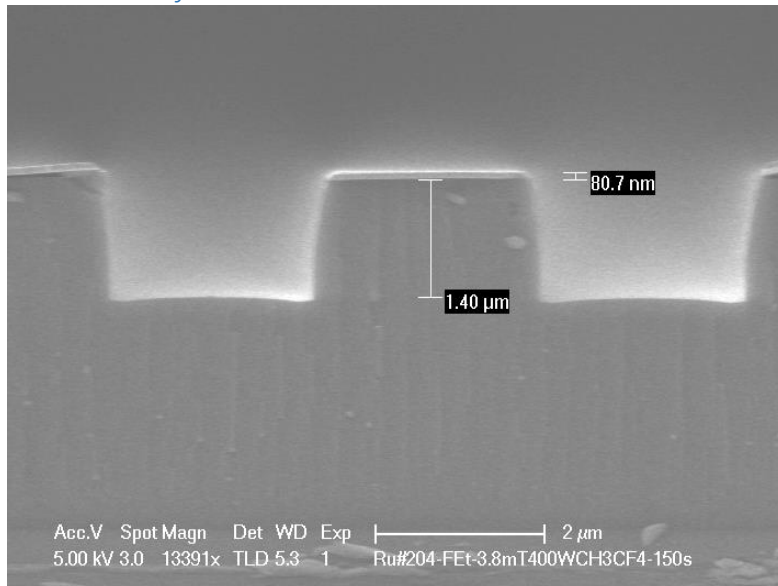
400W Bias Results

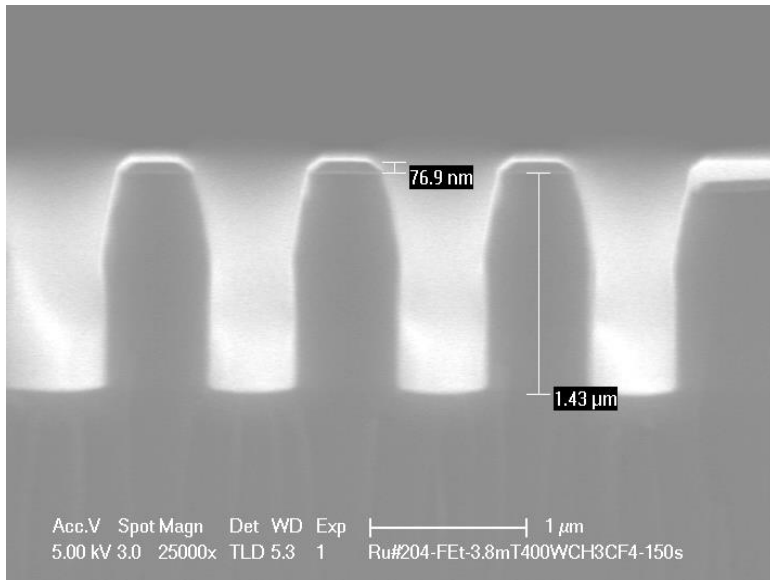
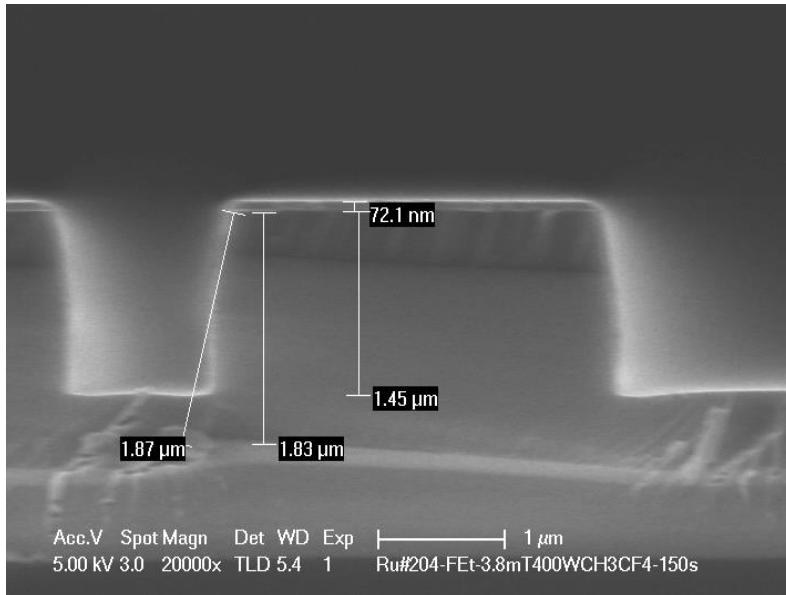
Average SiO₂ Etch rate=0.572 $\mu\text{m}/\text{min}$,

Etch Selectivity=17.0, Side-wall angle=78.4°

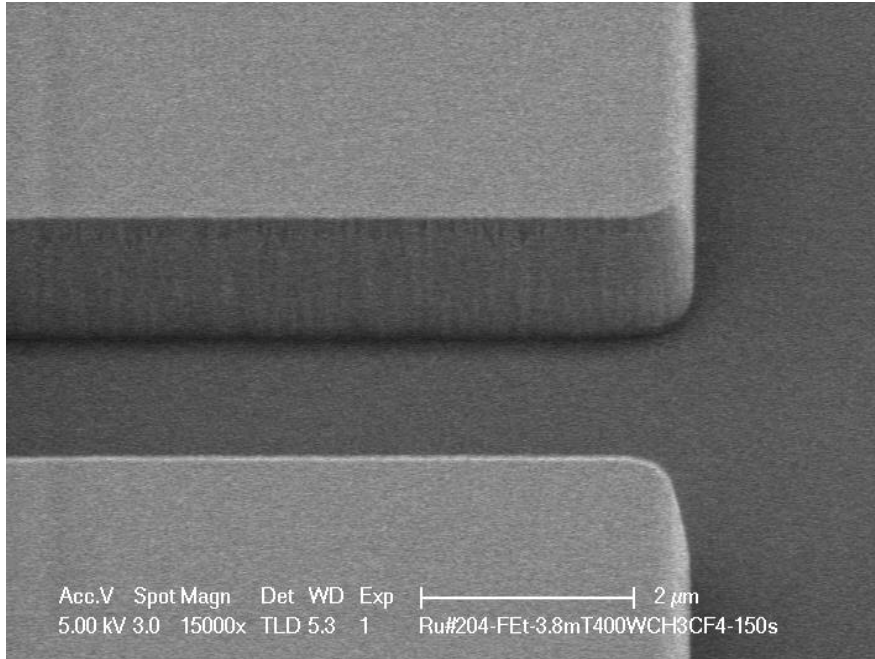
400W Bias SEMs

SiO₂ Etch Profile





Etched Side-wall Profile
Possibly Rougher sidewall



Varying Bias – Results Summary and Plots

SiO ₂ Etch with Ru Etch Mask using Florine ICP Tool, Varying Bias (3.8mT, ICP power=800W, CF ₄ /CHF ₃ Flow-rate=30/10 SCCM)		
Bias Power (W)	SiO ₂ Etch Rate (um/min)	Etch Selectivity (SiO ₂ /Ru)
50	0.263	36.4
200	0.471	37.7
400	0.572	17

