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UCSB NANOFAB

SiO_2 Etch using Ru Hardmask

Credit: Initial Ru/SiO_2 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 SiO_2 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 SiO_2 ≈ ~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

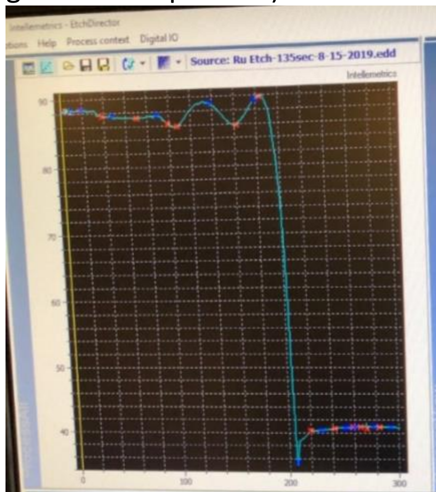
1. *Optional:* Solvent clean: acetone (2') + iso-propanol (1') in ultrasonic bath (HF) DI rinse and Dry in dryer
2. Bake at 135°C, 5 min (cooling on metal surface for 1 min)
3. Technics PEII: O2 descum, 300mT/100W, 1 min
4. Spin-on HMDS: 3500rpm, 30 sec (waiting for 20 sec before spinning)
5. Spin-on 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

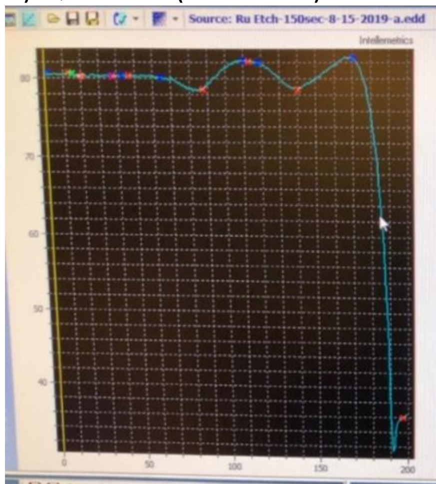
Ruthenium Etch Procedure

Tool: Panasonic ICP #1
Optional: Intellemetrics Laser Monitor
(Cleaved 100mm wafer into quarters)
Mount ¼ 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)

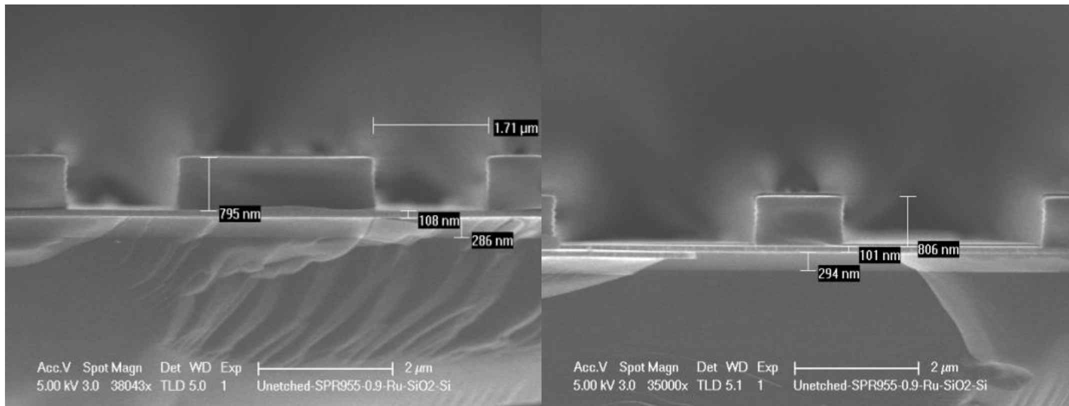


b) Quarter B (minor flat): Etch Time=150 sec (a little bit over etched)

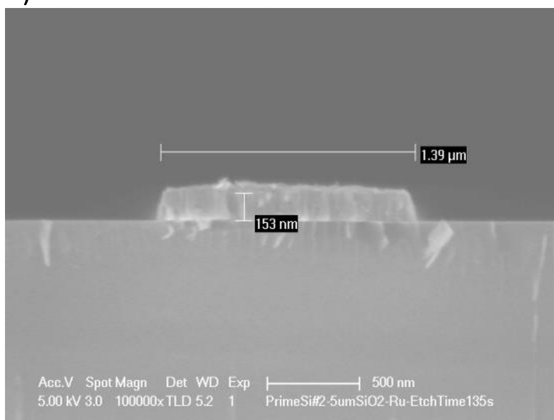


Ru etch profile (SEM)

a) Resist Etch Mask Profile before Ru dry etch

a. 

b) Ru Mask: etch Profile



SiO_2 Etch with Varying Bias

50W Bias SiO_2 Etch Procedure

Tool: Plasmatherm SLR Fluorine ICP

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

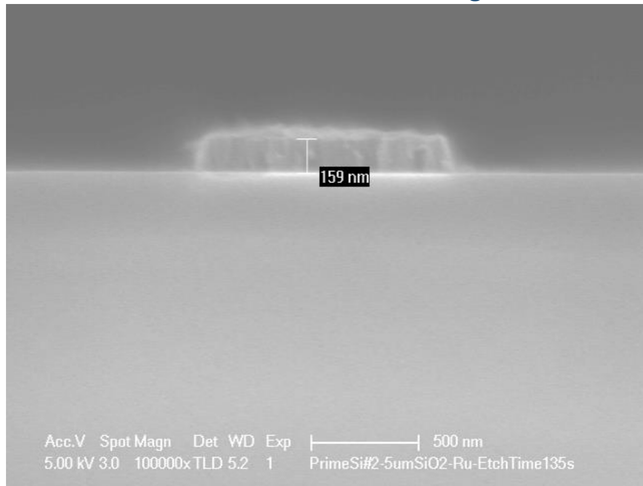
1. O2 clean chamber (O2 Clean-Useme-STDRCP), cleaning wafer
    a. 5mT, O2=100sccm, 10/850W, and time=30min
2. Chamber coating (carrier only): 30 sec of same recipe as below
3. Real samples (~1x1 cm2) etch run (2 samples: one with Ru etch mask, the other with PR mask)
    a. SiO2 Recipe: CHF3/CF4/SiO2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

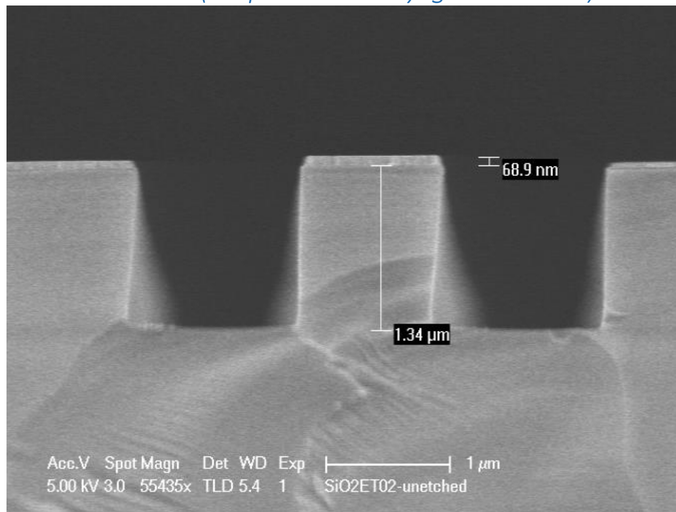
Average SiO2 Etch rate=0.263 um/min,
Etch Selectivity=36.4

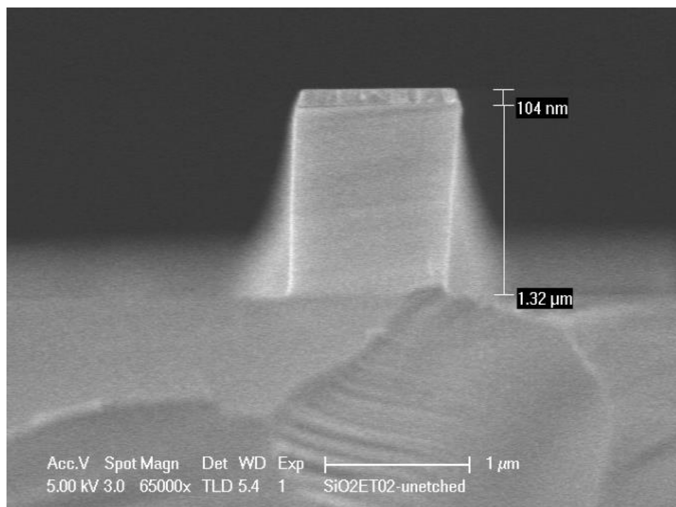
50W Bias SEMs

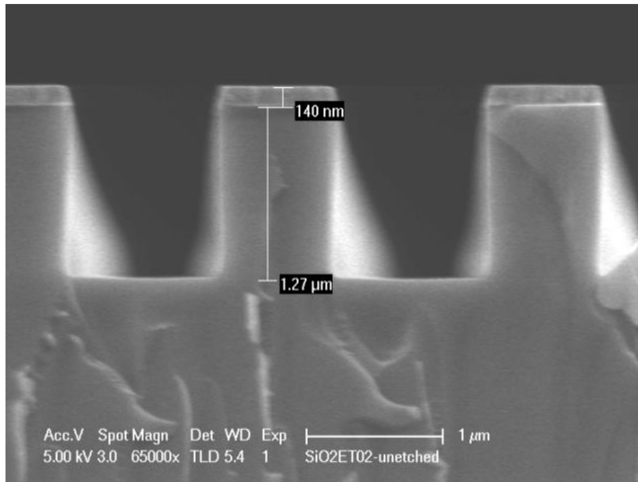
Ru Etch Mask Profile before SiO2 etching

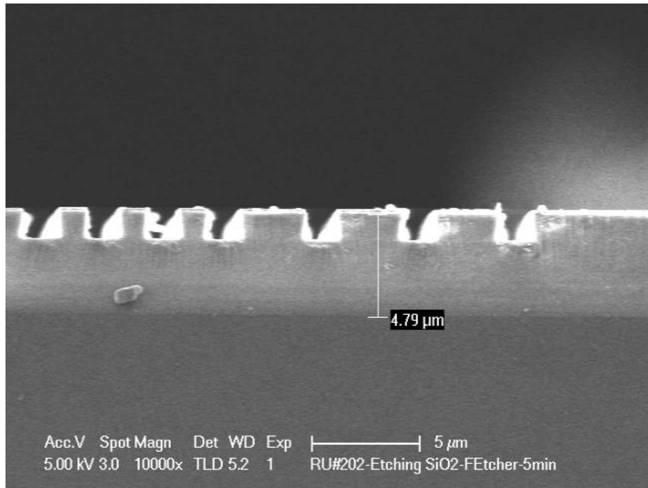


50W Bias SiO2 (~5 µm thermally-grown oxide) Etch Profile

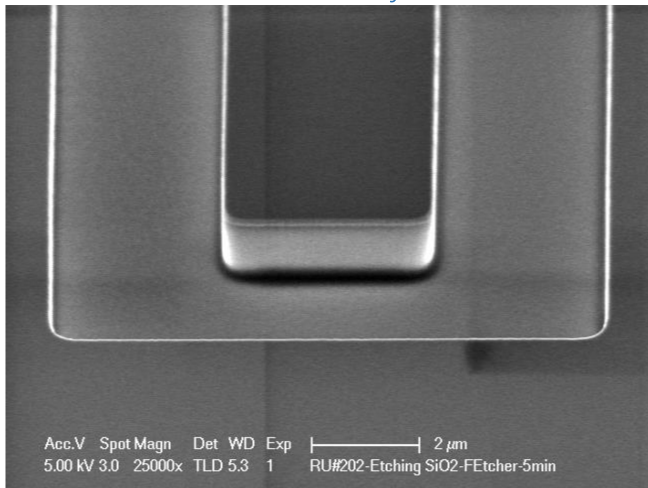


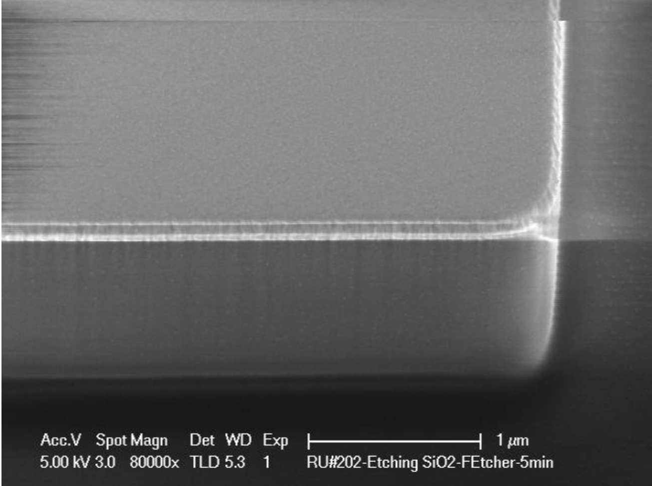






50W Bias Etched Side-wall Profile




Acc.V Spot Magn Det WD Exp
5.00 kV 3.0 80000x TLD 5.3 1
1 µm
RU#202-Etching SiO2-FEtcher-5min

200W Bias SiO_2 Etch using Ru etch mask

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

SiO_2 Etch Procedure

1) O2 clean chamber (O2 Clean-Useme-STDRCP) 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

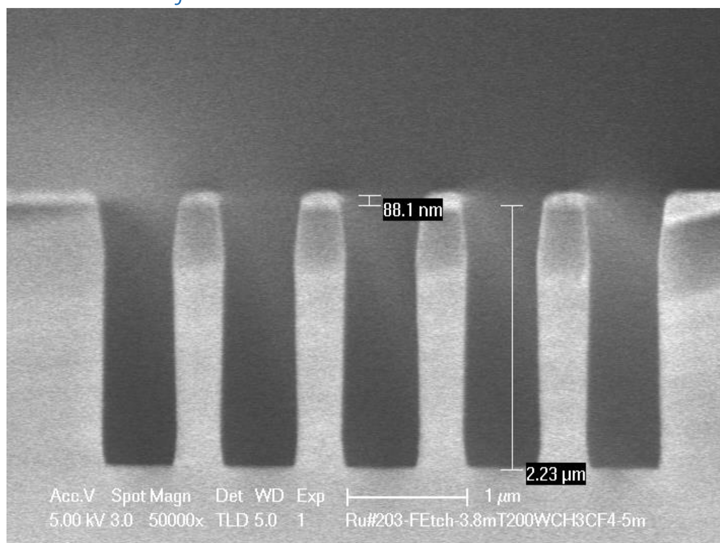
200W Bias Results

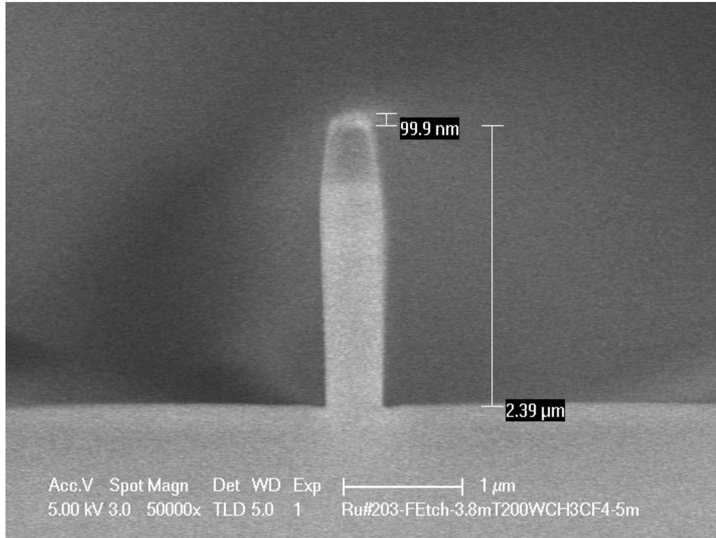
Average SiO2 Etch rate=0.471 um/min,

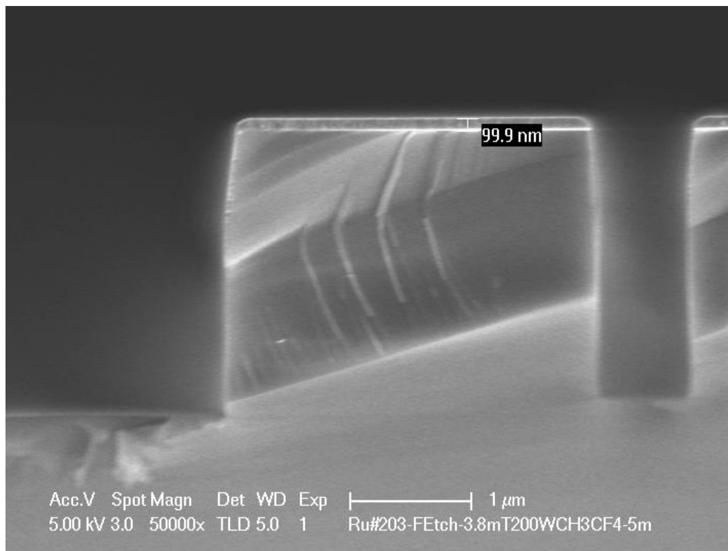
Etch Selectivity=37.7

200W Bias SEMs

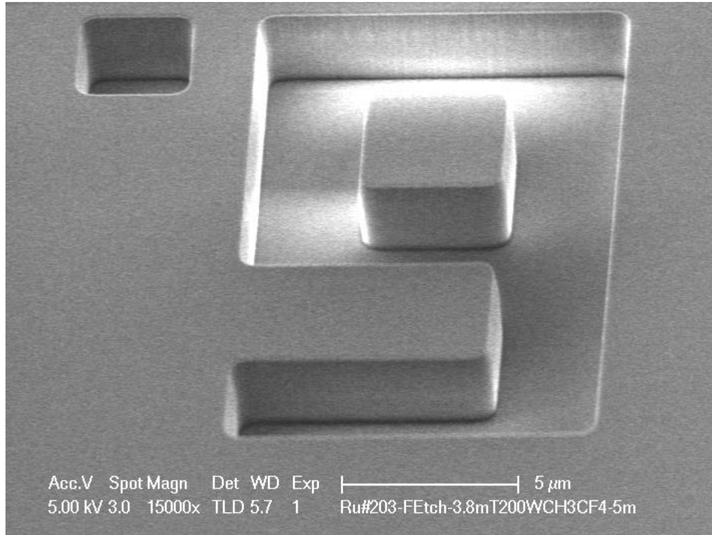
SiO2 Etch Profile

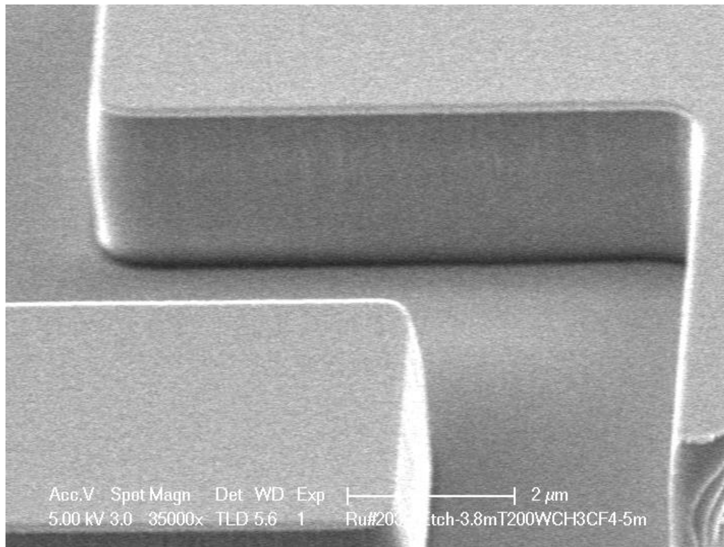



99.9 nm
2.39 µm
Acc.V Spot Magn Det WD Exp
1 µm
5.00 kV 3.0 50000x TLD 5.0 1 Ru#203-FEtch-3.8mT200WCH3CF4-5m


99.9 nm
Acc.V Spot Magn Det WD Exp
1 µm
5.00 kV 3.0 50000x TLD 5.0 1 Ru#203-FEtch-3.8mT200WCH3CF4-5m

Etched Side-wall Profile





400W Bias: SiO_2 Etch using Ru etch mask

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

SiO_2 Etch Procedure:

Tool: Plasmatherm SLR Fluorine ICP

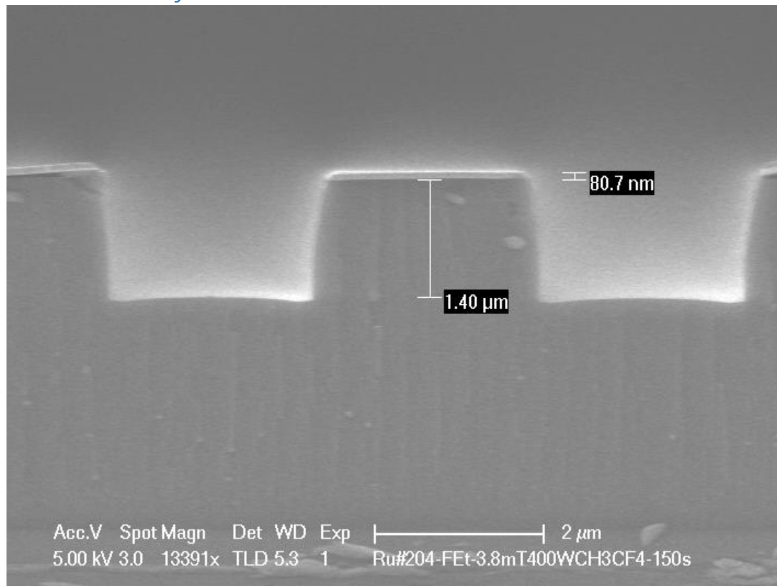
1) O2 clean chamber (O2 Clean-Useme-STDRCP) 5mT, O2=100sccm, 10/850W, and time=30min
2) Chamber coating (carrier only): 30 sec
3) Real samples (~1x1 cm2) etch run
   Recipe: CHF3/CF4/SiO2 Etch-cao
   3.8mT, RF/ICP = **400**/800W, CF4/CHF3=30/10 sccm, and time=2.5 min (150 sec)
   - (Bias Voltage=390-410V)
4) O2 chamber clean after etch: 15 min

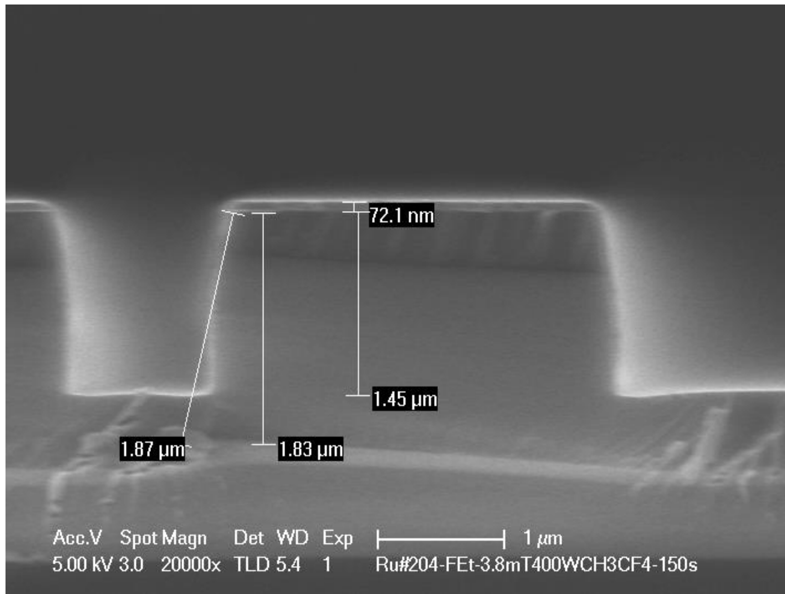
400W Bias Results

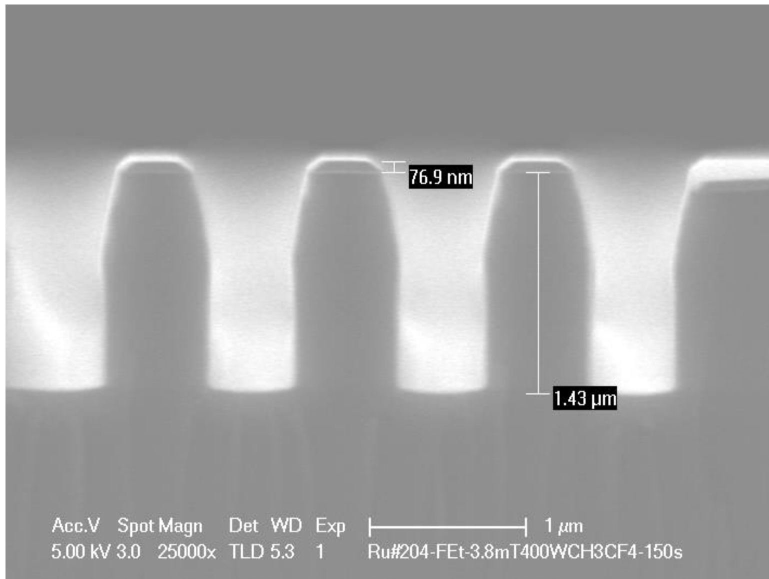
Average SiO2 Etch rate=0.572 um/min,
Etch Selectivity=17.0, Side-wall angle=78.4^{o}

400W Bias SEMs

SiO2 Etch Profile

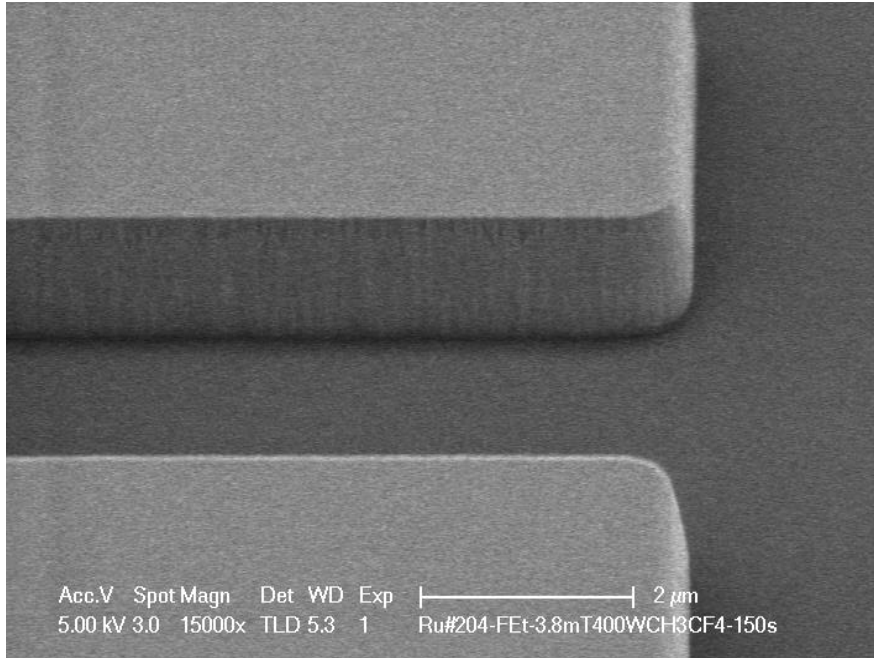






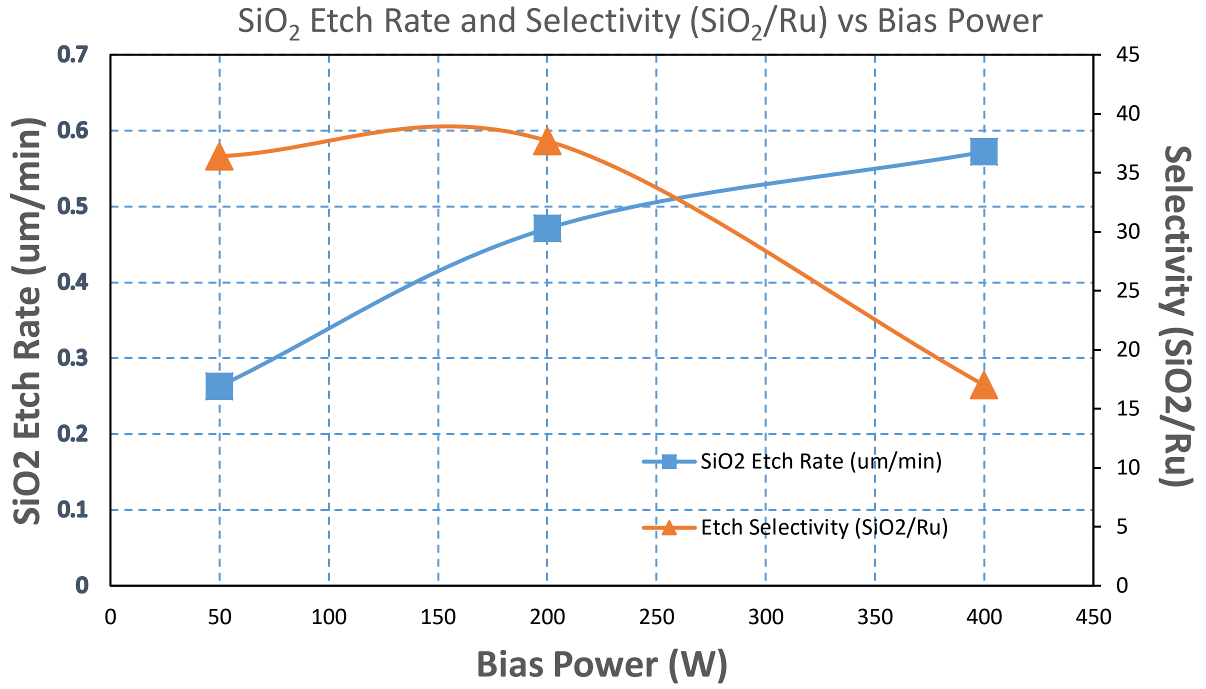
Etched Side-wall Profile

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, CF4/CHF3 Flow-rate=30/10 SCCM)		
Bias Power (W)	SiO2 Etch Rate (um/min)	Etch Selectivity (SiO2/Ru)
50	0.263	36.4
200	0.471	37.7
400	0.572	17


SiO_2 Etch Rate and Selectivity (SiO_2/Ru) vs Bias Power
SiO2 Etch Rate (um/min)
Selectivity (SiO2/Ru)
Bias Power (W)
SiO2 Etch Rate (um/min)
Etch Selectivity (SiO2/Ru)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
5
10
15
20
25
30
35
40
45
0
50
100
150
200
250
300
350
400
450