

## Undercut of Unaxis-ICP-Deposited-SiO<sub>2</sub>, by Vapor HF Etch

**Objective:** To study the undercut-etch-rate of high-density-plasma-CVD (HDPCVD)-grown SiO<sub>2</sub> using the Vapor HF tool with the currently installed recipes.

**Experimental:**

- 1) Solvent clean of a 4" Si wafer with acetone [2 minutes in a ultrasonic bath (USB)] and methanol (1 minute in a USB), then, DI water rinse, then, dipping the wafer into BHF to remove the native oxide for 1 minute, DI water rinse and nitrogen-gun blow dry.
- 2) Depositing HDPCVD SiO<sub>2</sub> onto the wafer surface using Unaxis ICP Deposition tool at 100 °C for 1000 seconds (15mT, 5/400W, SiH<sub>4</sub>/O<sub>2</sub>/He flow-rate=5.9/10/245 sccm). The film thickness and refractive index, measured with the Ellipsometer, are 553.7nm and 1.468, respectively.
- 3) Depositing an Aluminum layer, as an etch mask, onto the SiO<sub>2</sub> using E-beam#4 Evaporator: nominal thickness was 500nm (0.3nm/s).
- 4) A photoresist trench pattern was formed on the top of Aluminum layer using MA-6 mask aligner and AZ5214 resist (with image-reversal process).
- 5) Etching the Aluminum using Panasonic ICP#1 tool with 0.7 Pa, 70/300 W, BCl<sub>3</sub>/Cl<sub>2</sub> flow-rate=20/40 sccm, and etch time=80 seconds. After the etching, stripping the remaining resist using 1165 striper (at 80 °C on a hot-plate for 2 hours), and O<sub>2</sub> plasma descum (300mT/200W for 7 minutes).
- 6) Etching the underneath SiO<sub>2</sub> using Panasonic ICP#2 tool with 0.5 Pa, 200/900 W, CHF<sub>3</sub> flow-rate=40 sccm, and time=120 seconds.
- 7) Cleaving the wafer into small pieces (~1X1 cm<sup>2</sup>), then, baking them on a hot-plate at 220 °C for 10 minutes.
- 8) Etching samples using the Vapor HF (VHF) etch tool (SPTS μEtch System) with the currently installed standard recipes.
- 9) Cleaving the samples and taking SEMs to get the both undercut profile and undercut etch rate.

**Table 1** Recipes installed in the VHF etch tool (SPTS  $\mu$ Etch System).

Recipe#	Regulator	Pressure (T)	Gas (vapor) Flow-rate (sccm)		
			N2	EtOH	HF
1	7.0	125	1425	210	190
2	7.0	125	1250	350	310
3	7.0	125	1000	400	525
4	7.0	125	910	400	600
5	7.0	125	880	325	720

**Results:**

Figure 1 (a) and (b): Profile (the top and the bottom layer are Aluminum and SiO<sub>2</sub> one, respectively) after Aluminum etch using Panasonic ICP#1 with 0.7 Pa, 70/300 W, BCl<sub>3</sub>/Cl<sub>2</sub> flow-rate=20/40 sccm, and etch time=80 seconds.

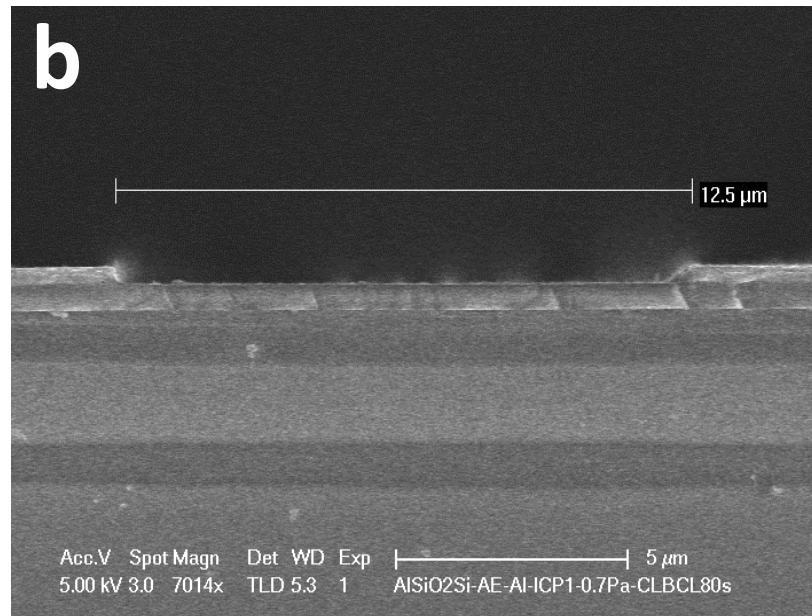
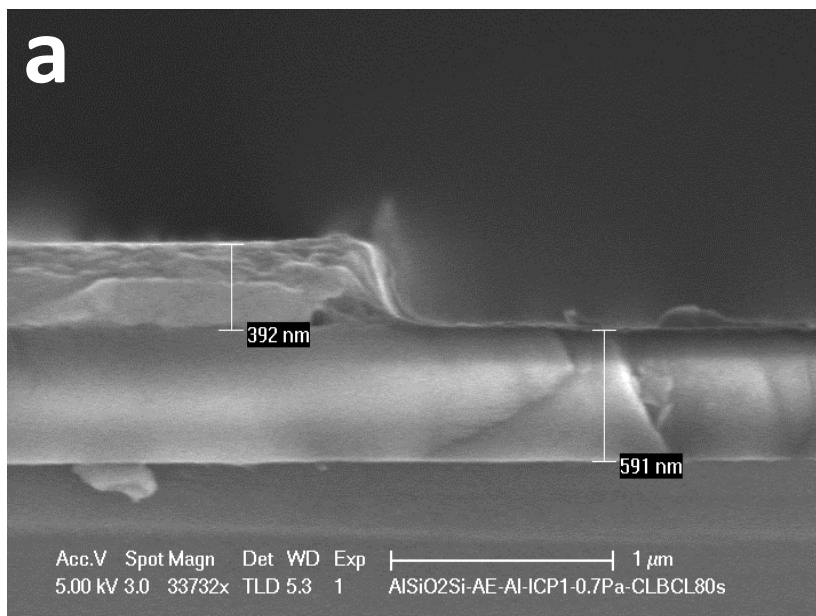


Figure 2 (a) and (b): Profile (the top and the bottom layer are Aluminum and SiO<sub>2</sub> one, respectively) after Aluminum etch (see Figure 1) and SiO<sub>2</sub> etch (using Panasonic ICP#2 with 0.5 Pa, 200/900 W, CHF<sub>3</sub> flow-rate=40 sccm, and etch time=120 seconds).

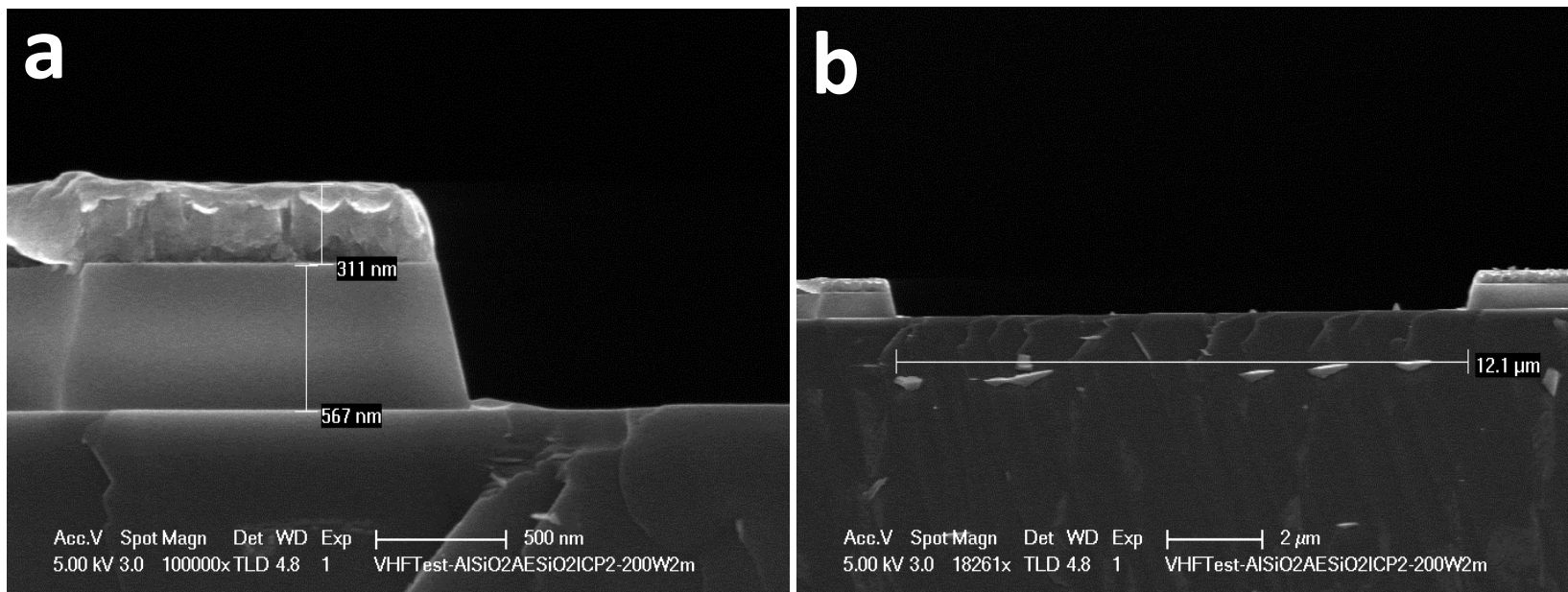
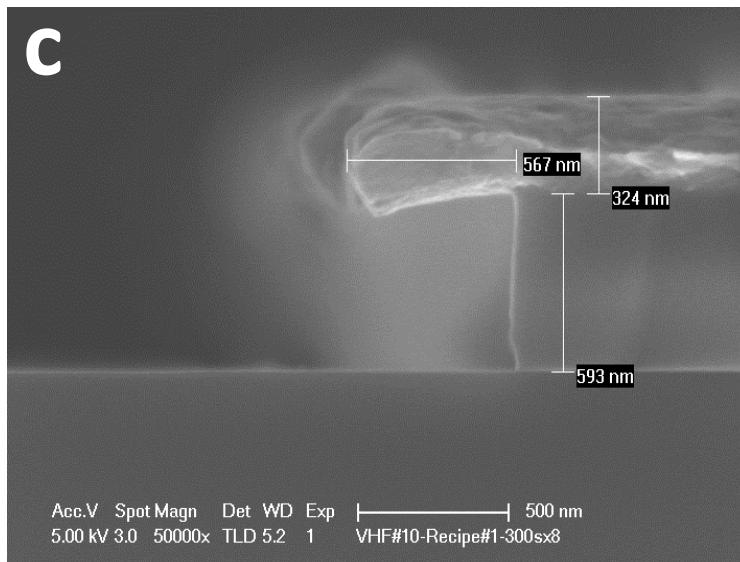
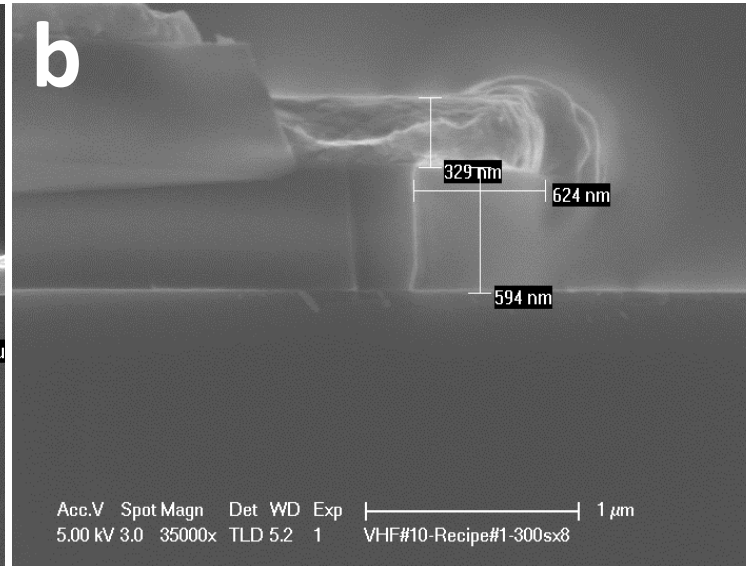
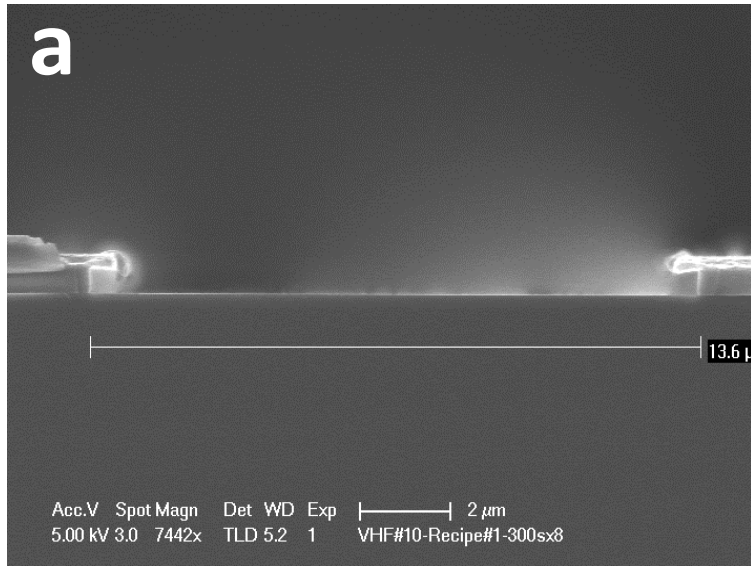


Figure 3 (a), (b), and (c): Dry etch profile of SiO<sub>2</sub> using VHF tool and **Recipe#1 with 8X300 s** (8 cycles and 300 s for each cycle).

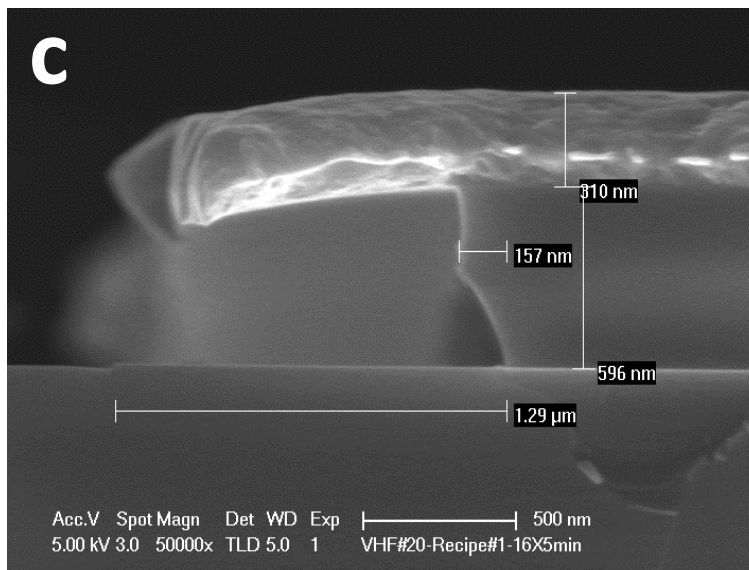
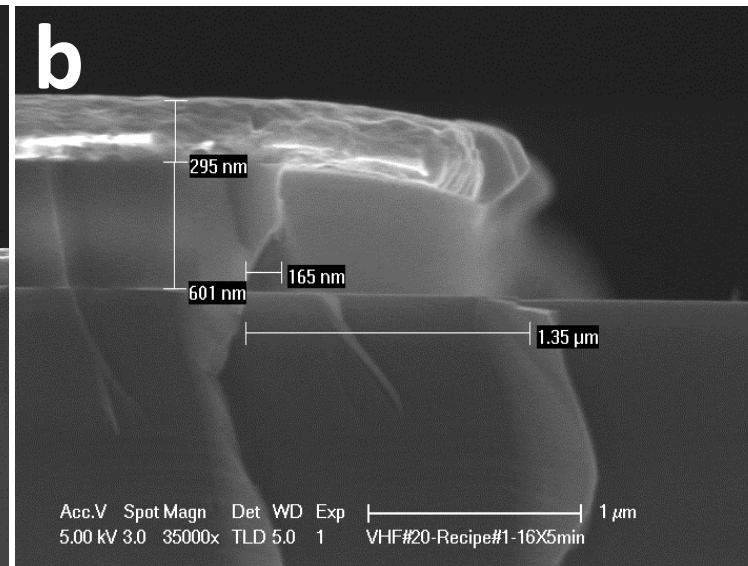
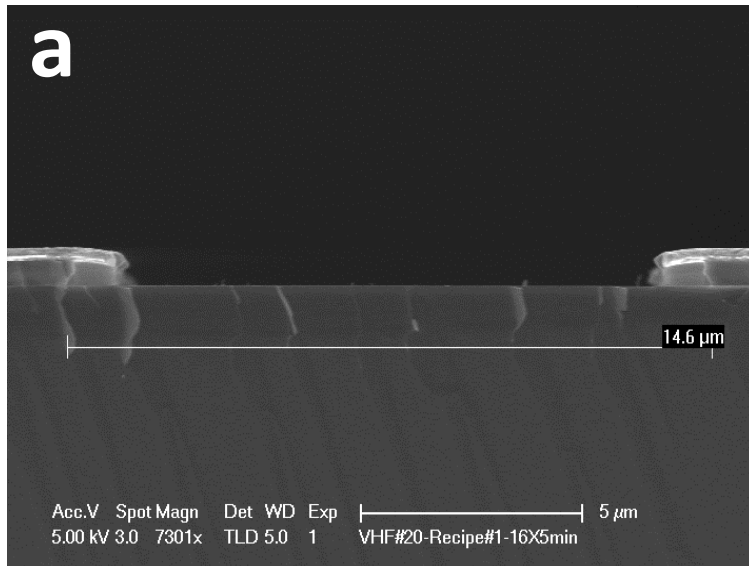


**Average opening width (including the undercuts) = 13.6 μm**

**Average Undercut= (13.6-12.1)/2≈0.75μm**

**Undercut etch rate=0.75μm/40min=190 Å/min**

Figure 4 (a), (b), and (c): Dry etch profile of SiO<sub>2</sub> using VHF tool and **Recipe#1 with 16X300 s** (16 cycles and 300 s for each cycle).

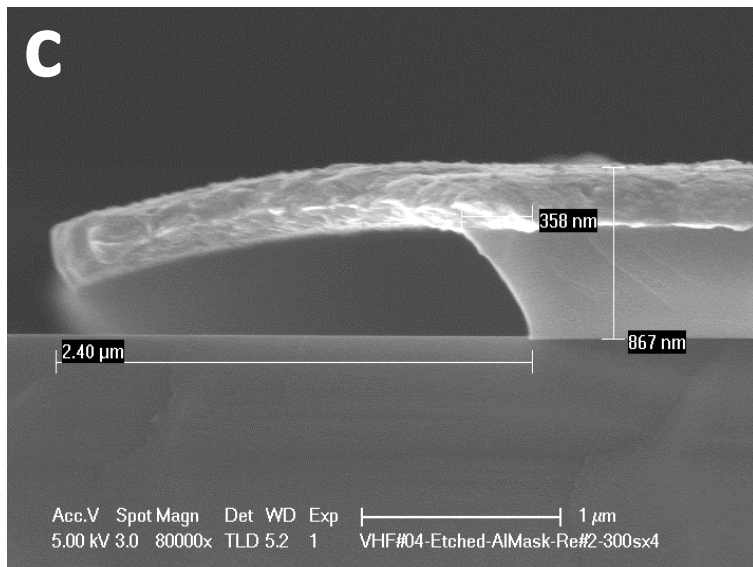
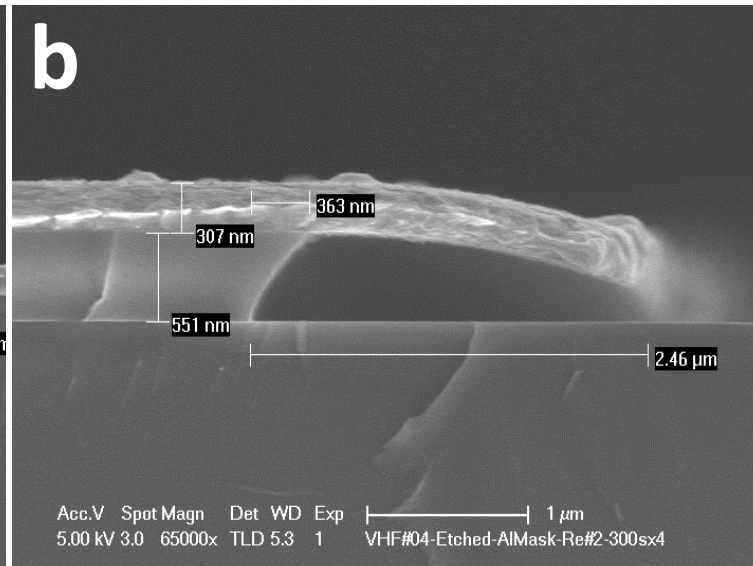
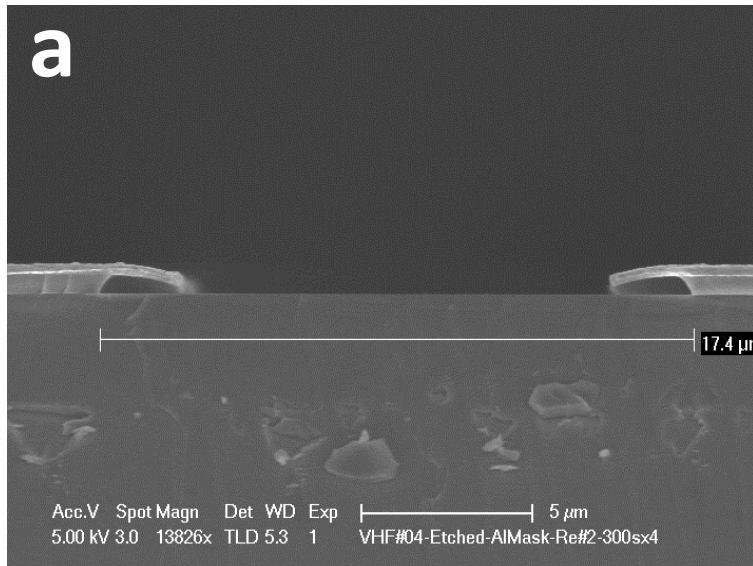


**Average opening width (including the undercuts) = 14.7  $\mu\text{m}$**

**Average Undercut= (14.7-12.1)/2 $\approx$ 1.3  $\mu\text{m}$**

**Undercut etch rate=1.3  $\mu\text{m}$ /80min=163  $\text{\AA}$ /min**

Figure 5 (a), (b), and (c): Dry etch profile of SiO<sub>2</sub> using VHF tool and **Recipe#2 with 4X300 s** (4 cycles and 300 s for each cycle).

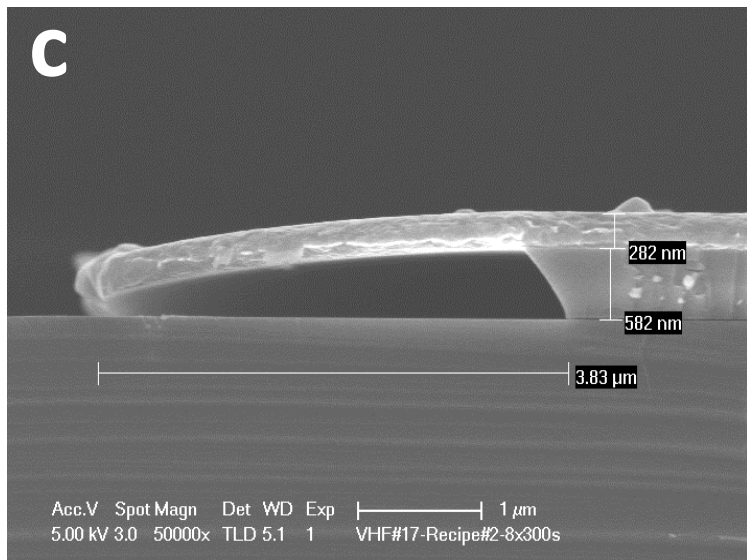
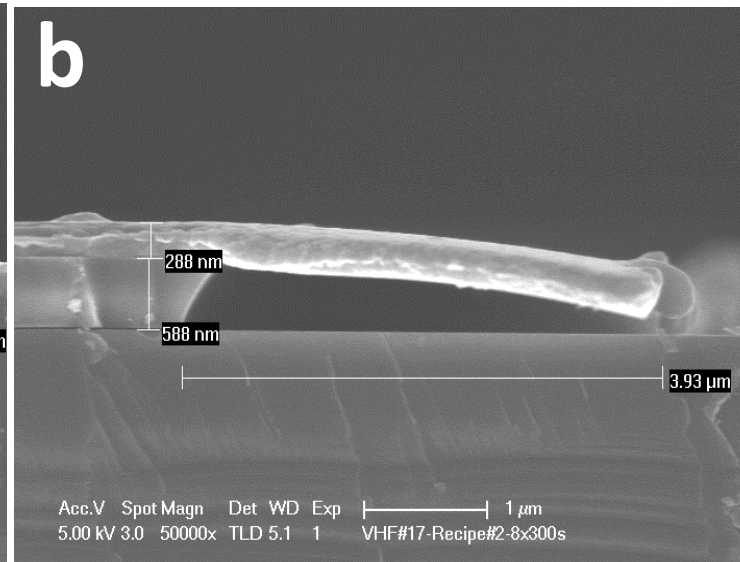
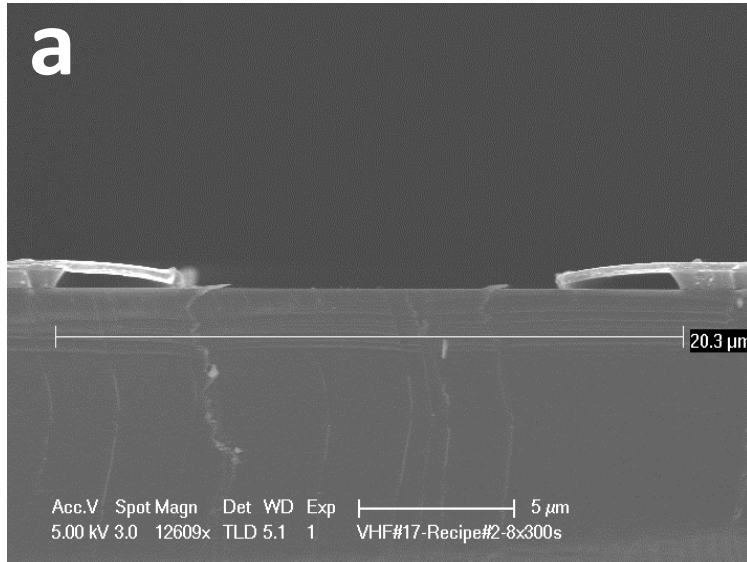


**Average opening width (including the undercuts)**  
**= 17.4 μm**

**Average Undercut = (17.4 - 12.1) / 2 ≈ 2.65 μm**

**Undercut etch rate = 2.65 μm / 20 min = 1330 Å/min**

Figure 6 (a), (b), and (c): Dry etch profile of SiO<sub>2</sub> using VHF tool and **Recipe#2 with 8X300 s** (8 cycles and 300 s for each cycle).



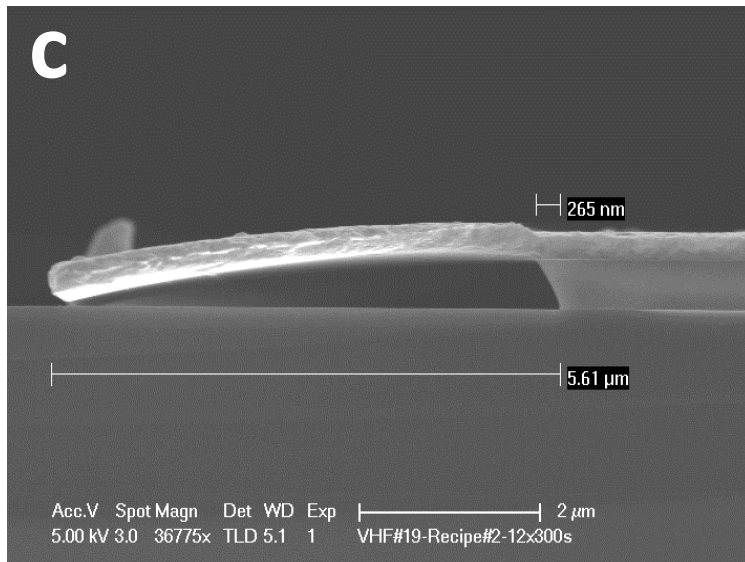
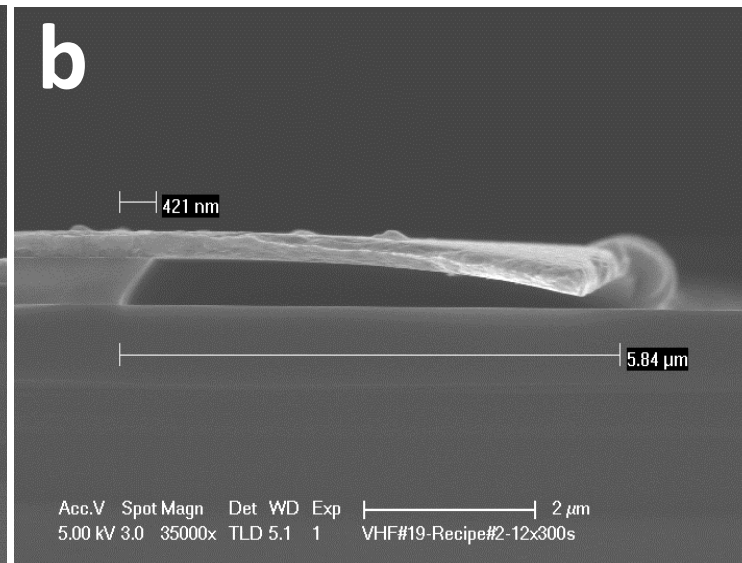
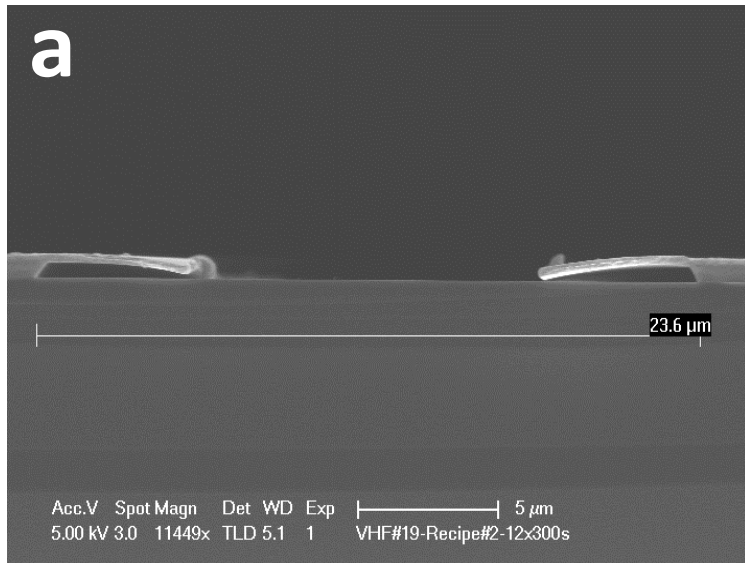
**Average opening width (including the undercuts) = 20.3  $\mu\text{m}$**

**Average Undercut =  $(20.3 - 12.1) / 2 \approx 4.1 \mu\text{m}$**

**Undercut etch rate =  $4.1 \mu\text{m} / 40 \text{min} = 1030 \text{ \AA} / \text{min}$**



Figure 7 (a), (b), and (c): Dry etch profile of SiO<sub>2</sub> using VHF tool and **Recipe#2 with 12X300 s** (12 cycles and 300 s for each cycle).



**Average opening width (including the undercuts) = 23.4 μm**

**Average Undercut = (23.4 - 12.1) / 2 ≈ 5.65 μm**

**Undercut etch rate = 5.65 μm / 60 min = 940 Å/min**

Figure 8 SiO<sub>2</sub> undercut vs. etch time using Recipe#2.

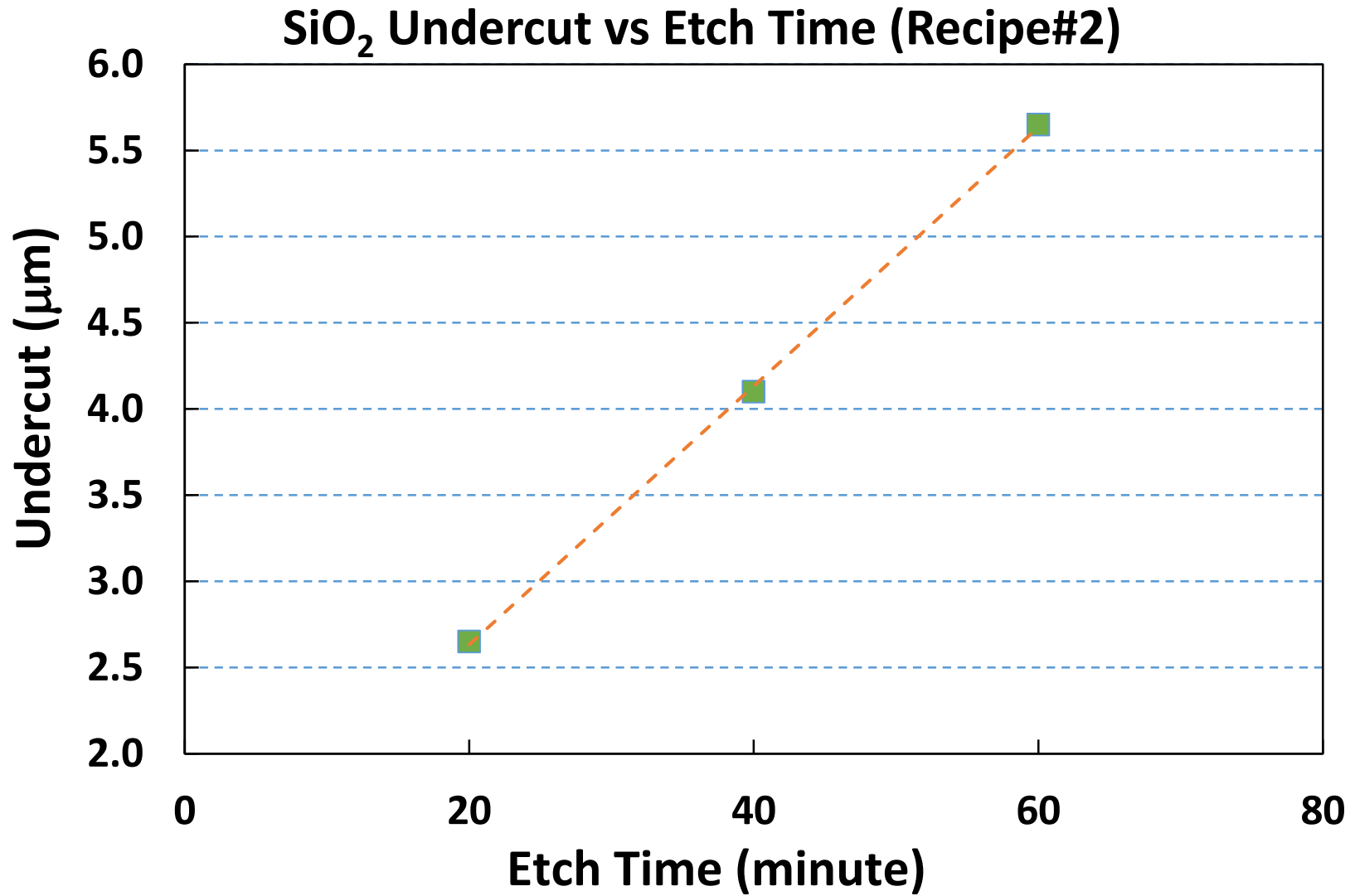
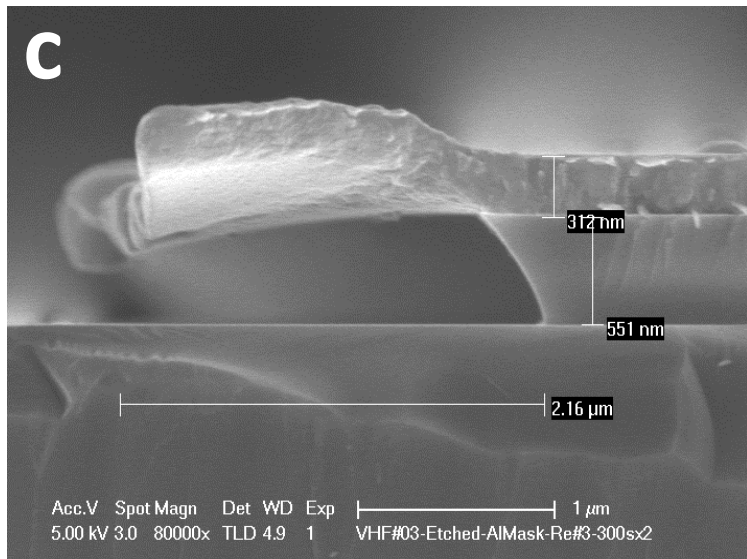
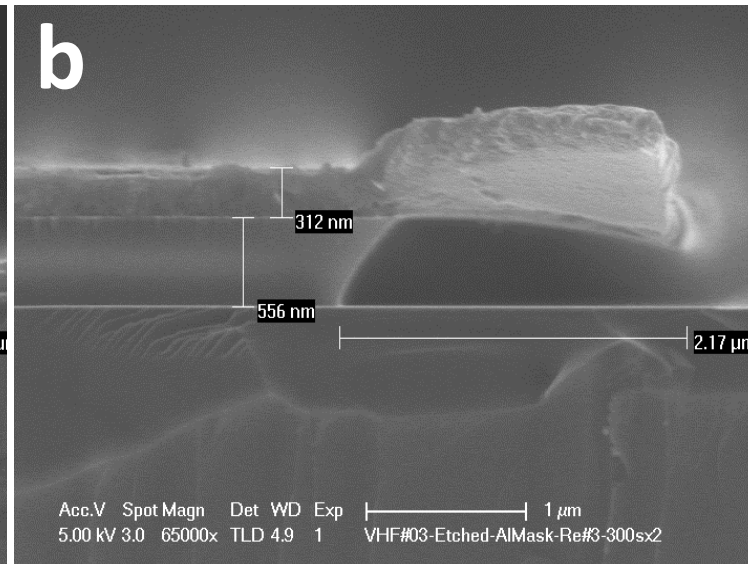
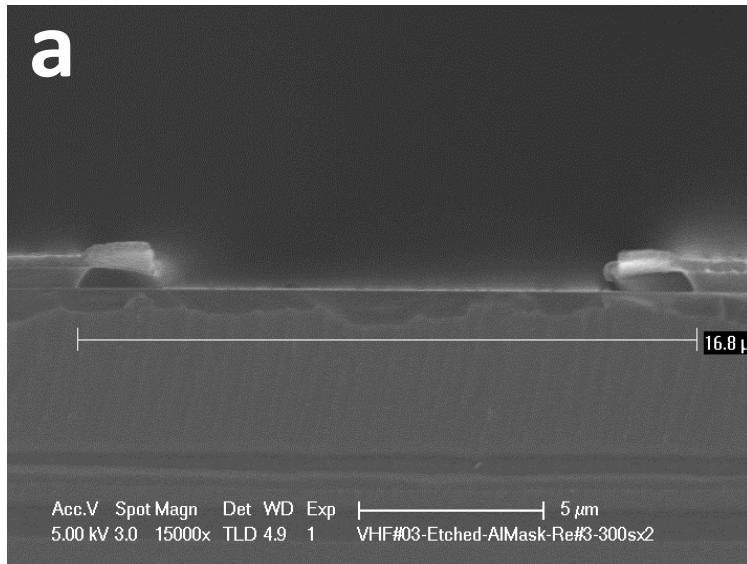


Figure 9 (a), (b), and (c): Dry etch profile of SiO<sub>2</sub> using VHF tool and **Recipe#3 with 2X300 s** (2 cycles and 300 s for each cycle).

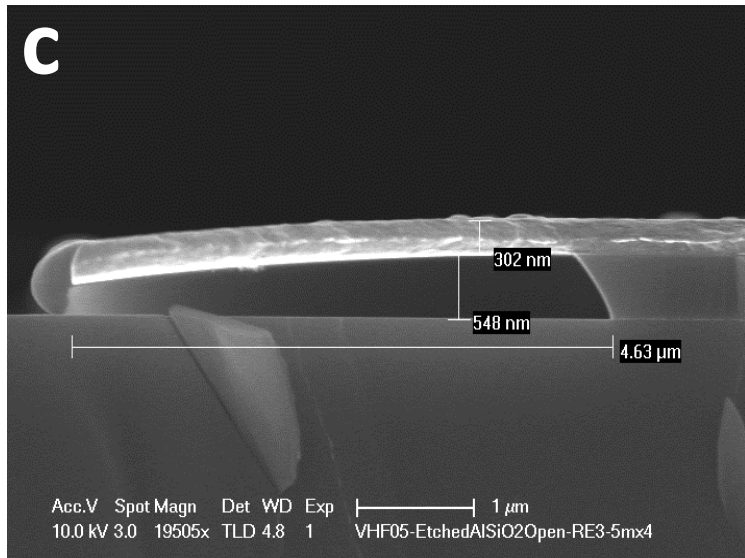
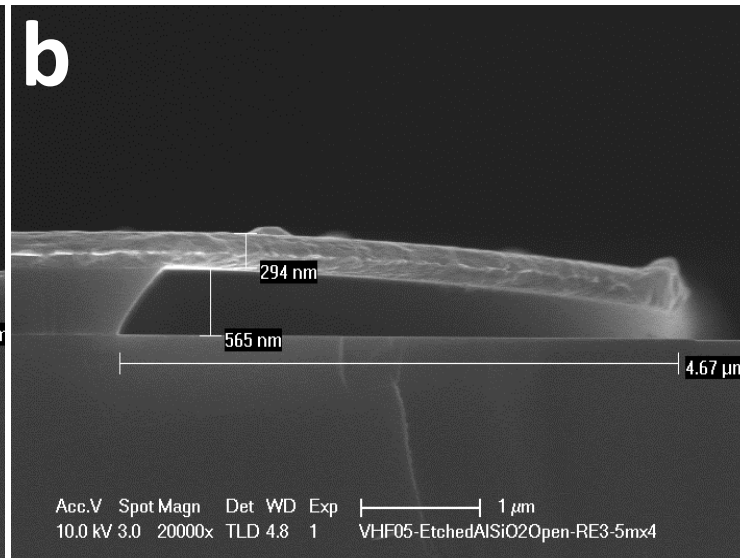
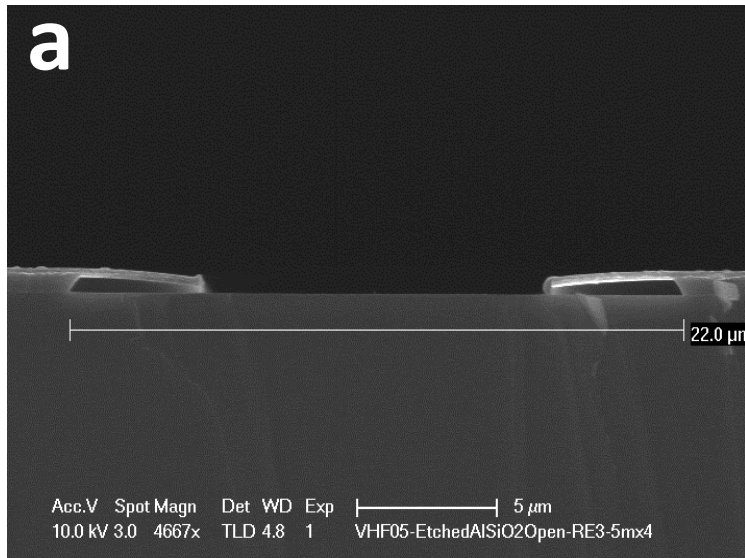


**Average opening width (including the undercuts) = 16.8 μm**

**Average Undercut =  $(16.8 - 12.1) / 2 \approx 2.35 \mu\text{m}$**

**Undercut etch rate =  $2.35 \mu\text{m} / 10 \text{min} = 2350 \text{ \AA} / \text{min}$**

Figure 10 (a), (b), and (c): Dry etch profile of SiO<sub>2</sub> using VHF tool and **Recipe#3 with 4X300 s** (4 cycles and 300 s for each cycle).

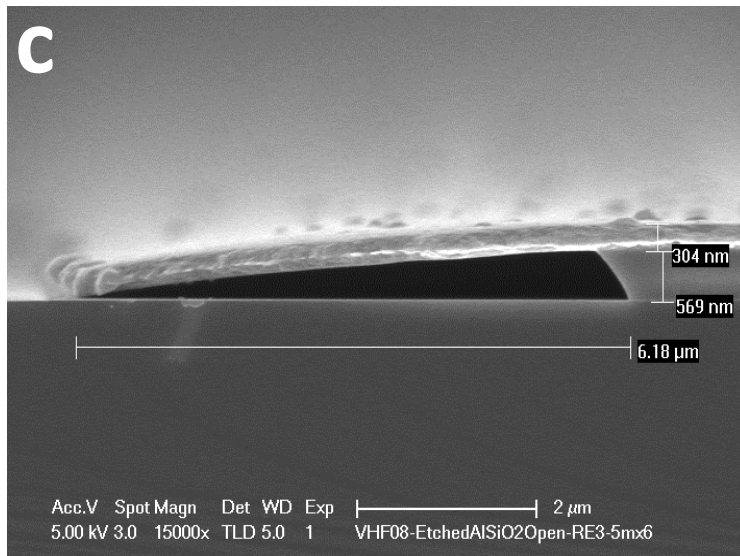
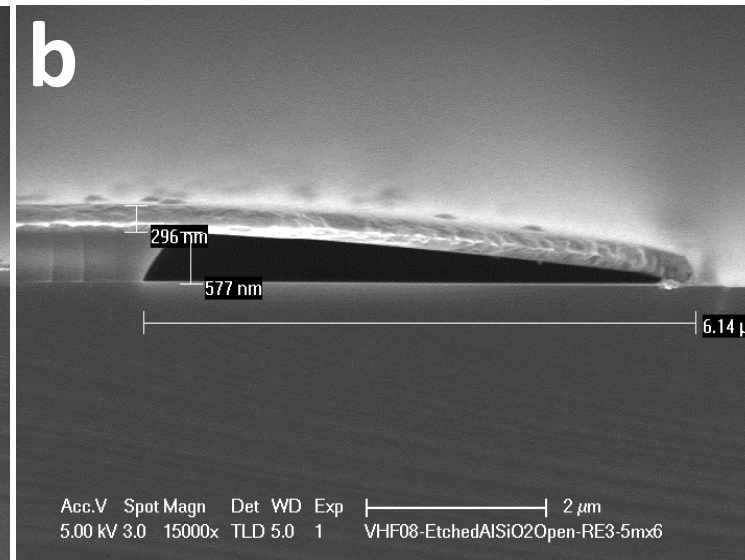
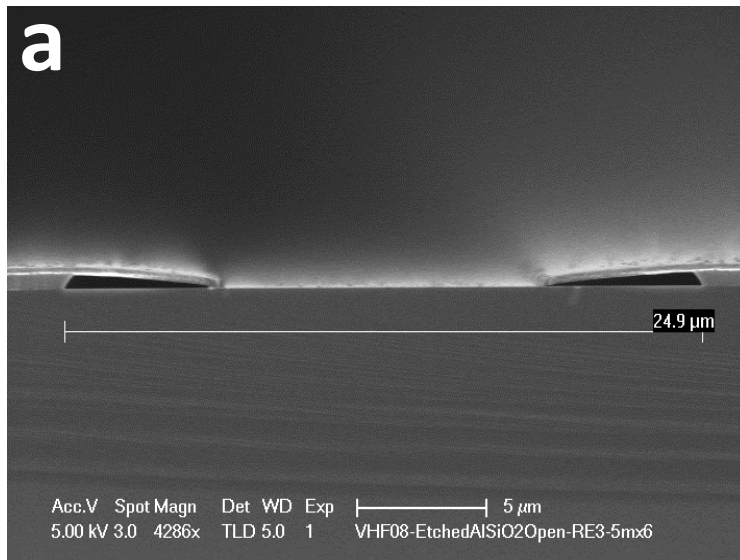


***Average opening width (including the undercuts) = 21.9  $\mu\text{m}$***

***Average Undercut= (21.9-12.1)/2 $\approx$ 4.9  $\mu\text{m}$***

***Undercut etch rate=4.9  $\mu\text{m}$ /20min $\approx$ 2450  $\text{\AA}$ /min***

Figure 11 (a), (b), and (c): Dry etch profile of SiO<sub>2</sub> using VHF tool and **Recipe#3 with 6X300 s** (6 cycles and 300 s for each cycle).

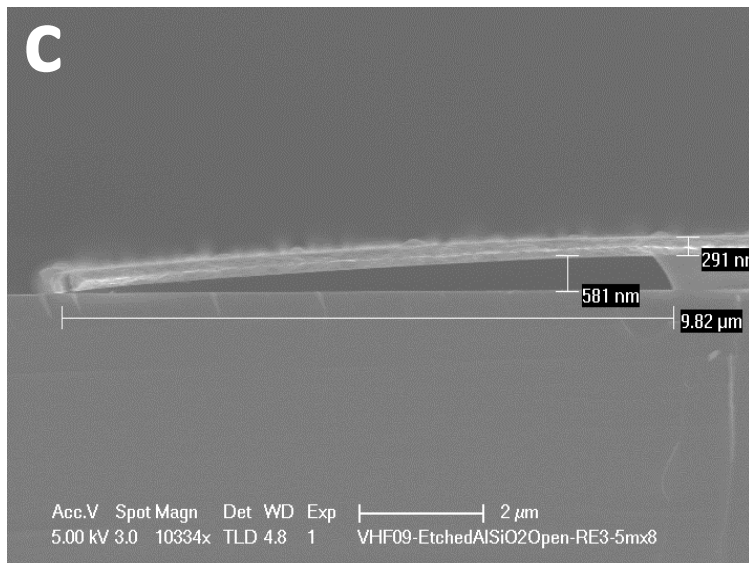
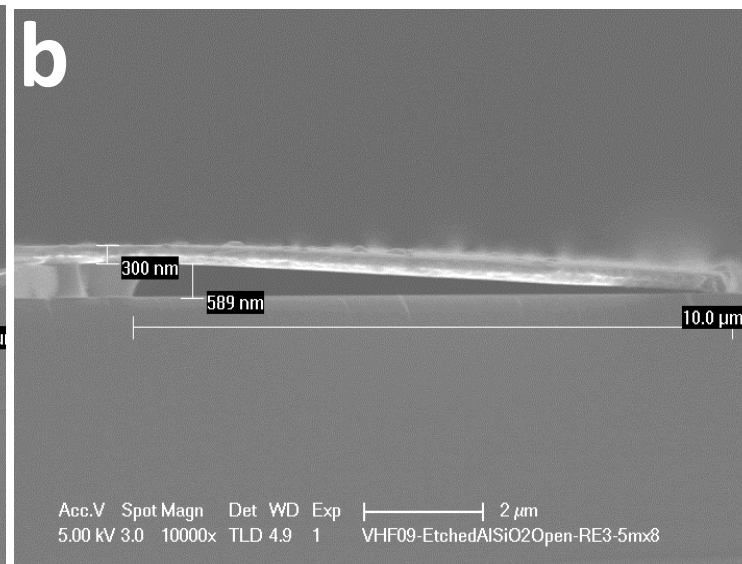
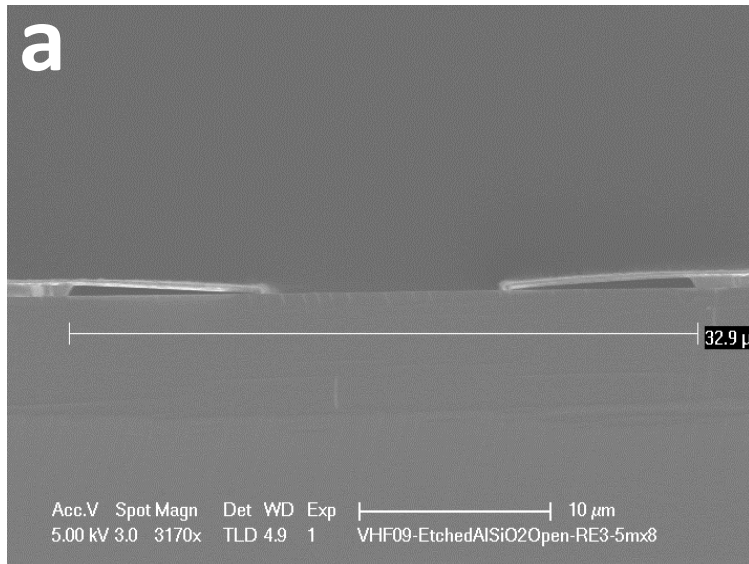


***Average opening width (including the undercuts)***  
***= 25.1  $\mu\text{m}$***

***Average Undercut= (25.1-12.1)/2 $\approx$ 6.5  $\mu\text{m}$***

***Undercut etch rate=6.5  $\mu\text{m}$ /30min $\approx$ 2170  $\text{\AA}$ /min***

Figure 12 (a), (b), and (c): Dry etch profile of SiO<sub>2</sub> using VHF tool and **Recipe#3 with 8X300 s** (8 cycles and 300 s for each cycle).

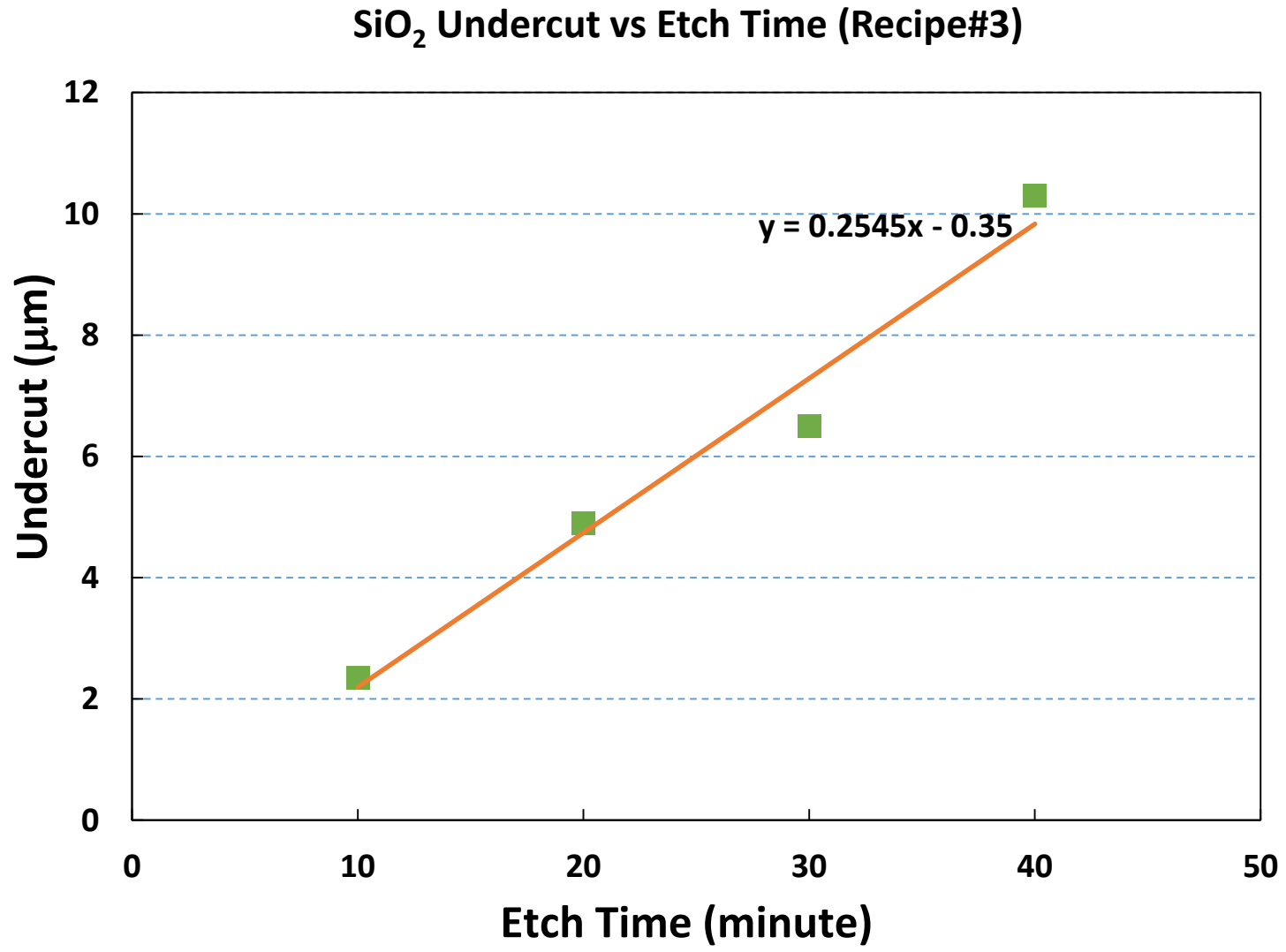


**Average opening width (including the undercuts) = 32.7  $\mu\text{m}$**

**Average Undercut= (32.7-12.1)/2 $\approx$ 10.3  $\mu\text{m}$**

**Undercut etch rate=10.3  $\mu\text{m}$ /40min $\approx$ 2580  $\text{\AA}$ /min**

Figure 13 SiO<sub>2</sub> undercut vs. etch time using Recipe#3.



**To Be Continued (see File#b)**