

## Etching Platinum using Oxford Ion Mill Tool

**Object:** To get the etch rate and selectivity ( $\text{Al}_2\text{O}_3$  as an etch mask), as well as etch profile, of Pt by using Oxford Ion Mill tool.

### Experimental:

- 1) **Wafer Clean:** three 4" Si wafers cleaned by a) soaking in acetone (2' in ultrasonic bath) and methanol (1' in ultrasonic bath), then, DI water rinse; b) dipping them in buffered HF in 1', then, DI water rinse and nitrogen gas blow dry.
- 2) **Depositing** Ti/Pt (10/500 nm: nominal thickness) using E-beam#4.
- 3) **Lithography** for making the etch pattern:
  - a) Dehydration bake at 115 C for 5 minutes.
  - b) Spinning-on HMDS: 3000 rpm for 30 s.
  - c) Spinning-on SF-8 (PMGI): 1500 rpm for 40 s.
  - d) Bake at 200 C for 3 minutes.
  - e) Spinning-on SPR955-0.9: 3000 rpm for 30 s.
  - f) Bake at 95 C for 90 s.
  - g) Exposing using Auto-stepper200 for shooting an 11X11 array with 0.35 s (Recipe name: Ning) using the calibration reticle.
  - h) Post Exposure bake at 110 C for 90 s.
  - i) Development in AZ300MIF for 3 minutes.
  - j)  $\text{O}_2$  plasma descum 300mT/100W 60 s.
- 4) **Depositing**  $\text{Al}_2\text{O}_3$  (target thickness: 350.3 nm, actual thickness: 305 nm, Tooling factor:  $305.3 \times 171.1 / 350 = 149.2$ ) using E-beam#2.

5) **Lifting-off Al<sub>2</sub>O<sub>3</sub>**: a) soaking in 1165 stripper in 80 C hot-water bath for 3.5 hours; b) soaking in fresh 1165 in 70 C hot-water ultrasonic wave bath for 3 minutes (ultrasonic wave was on); c) soaking in Isopropanol in room-temperature water ultrasonic wave bath for 2 minutes (ultrasonic wave was on), then, DI water rinse and nitrogen gas blow dry; d) Gasonics: recipe: #3 for 3 minutes.

6) **Cleaving** the wafer into sample pieces for ion-mill.

**Results:**

Table 1. Etch rate and selectivity (Pt/Al<sub>2</sub>O<sub>3</sub>), and side-wall angle of Pt under different ion-mill conditions (both Ar flow rates to neutralizer and beam are 5 sccm; platen and chamber wall temperatures are 10 and 40 C, respectively; platen rotation is 20 rpm).

Sample#	date	In (mA)	Prf (W)	Ib (mA)	Vb (V)	Va (V)	Incident Angle (°)	Etch Time (minute)	Etch Rate (nm/min)	Etch Selectivity (Pt/Al <sub>2</sub> O <sub>3</sub> )	Side-wall angle (°)
Pt01	6/24/2015	250	250	150	500	500	0	6	56.7	5.7	54.7
Pt02	6/24/2015	250	250	150	500	500	15	6	54.8	3.9	62.9
Pt03	6/24/2015	250	250	150	500	500	-15	6	56.7	5	61.9
Pt04	6/24/2015	250	250	150	500	500	-30	6	55.3	3.1	68.3
Pt05	6/25/2015	250	200	100	500	500	-15	9	38.3	5.9	58.1
Pt06	6/25/2015	250	250	150	500	250	15	6	66	4.1	60.7
Pt07	6/29/2015	250	250	150	500	500	30	6	52.7	2.7	64.1
Pt08	6/29/2015	250	250	150	500	500	45	6	45	1.6	71.7
Pt10	6/30/2015	250	200	150	250	500	-15	8	37.1	5	60
Pt12	7/1/2015	250	200	50	250	500	-15	25	11.3	5.5	60.1
Pt13	7/2/2015	250	150	50	500	500	-15	20	16.2	5	64.5
Pt14	7/2/2015	250	200	100	250	500	-15	15	22.9	5.8	60.2
Pt15	7/6/2015	250	150	50	125	500	-15	50	5.7	5.4	52.9
Pt16	7/7/2015	250	150	25	250	500	-15	50	5	5.5	55.4

Figure 1 Cross-section of Pt layer and Al<sub>2</sub>O<sub>3</sub> mask pattern before ion-mill.

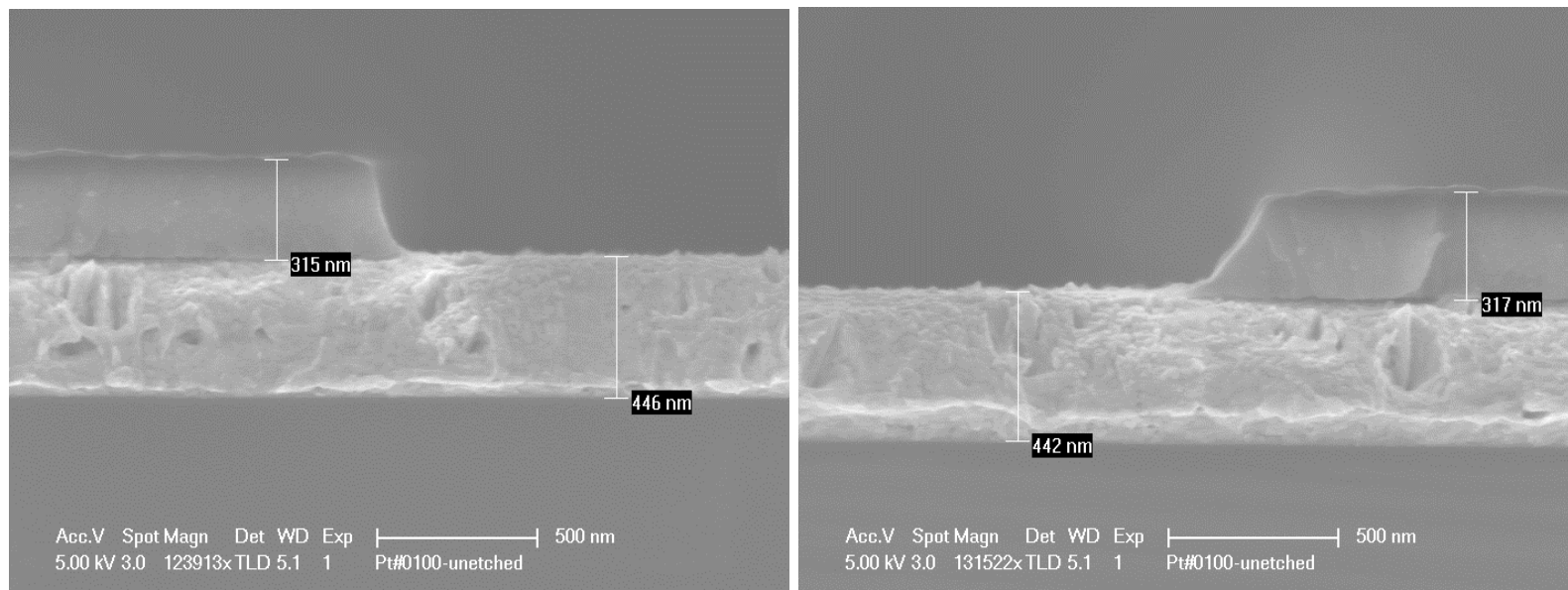


Figure 2 (a) and (b) Cross-section of the milled sample Pt01 with  $I_n=250\text{mA}$ ,  $P_{rf}=250\text{W}$ ,  $I_b=150\text{mA}$ ,  $V_b=500\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $0^\circ$ , and time=6 minutes.

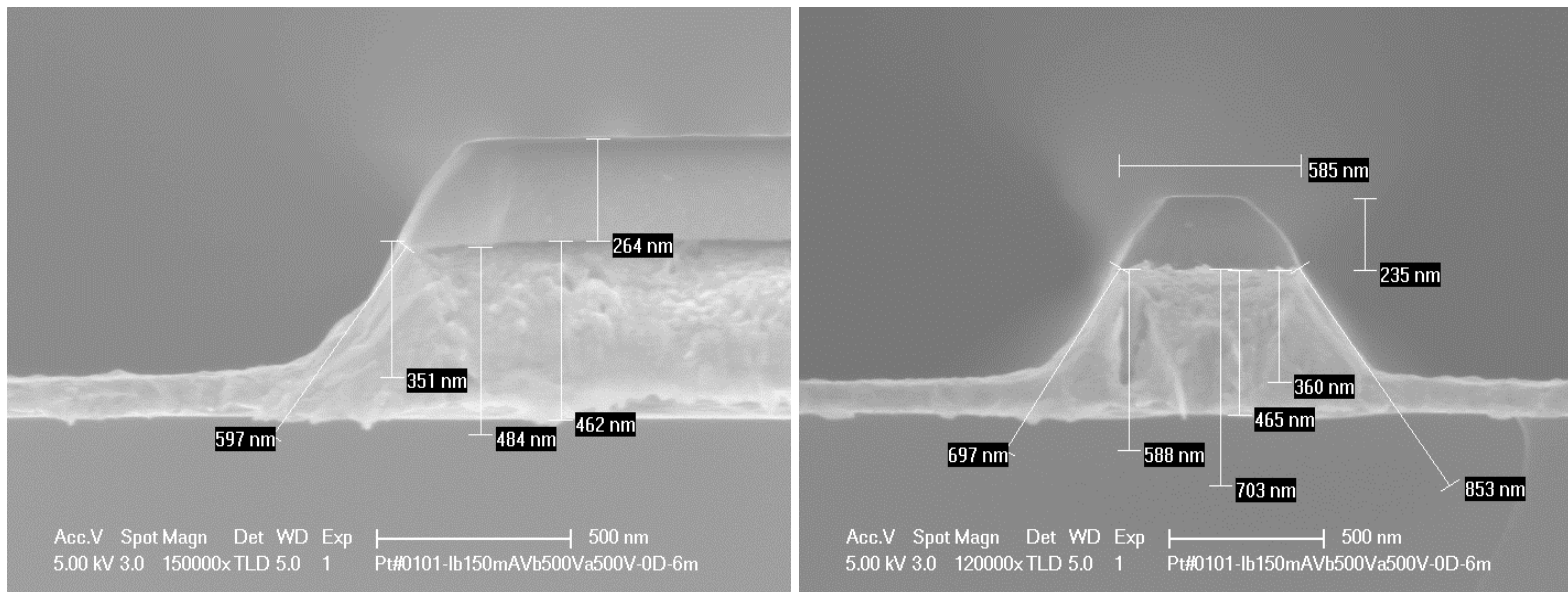


Figure 3 (a) and (b) Cross-section of the milled sample Pt02 with  $I_n=250\text{mA}$ ,  $P_{rf}=250\text{W}$ ,  $I_b=150\text{mA}$ ,  $V_b=500\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $15^\circ$ , and time=6 minutes.

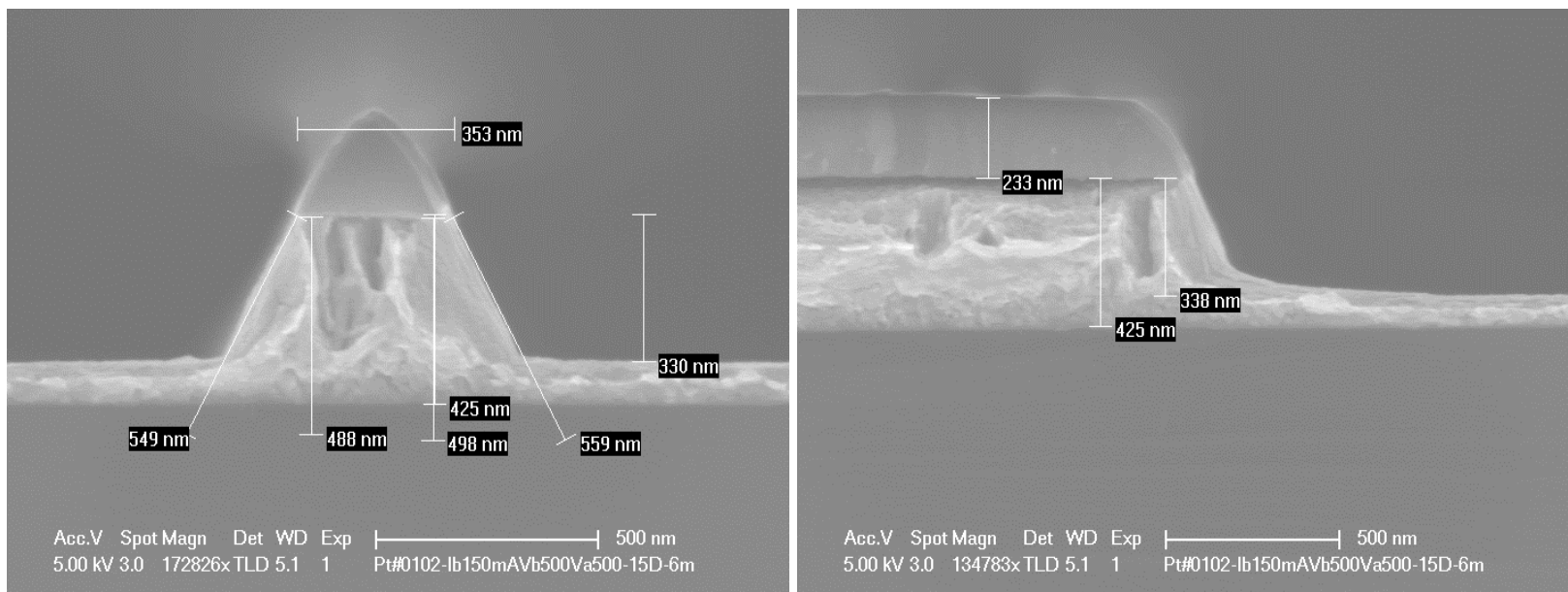


Figure 4 (a) and (b) Cross-section of the milled sample Pt03 with  $I_n=250\text{mA}$ ,  $P_{rf}=250\text{W}$ ,  $I_b=150\text{mA}$ ,  $V_b=500\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $-15^\circ$ , and time=6 minutes.

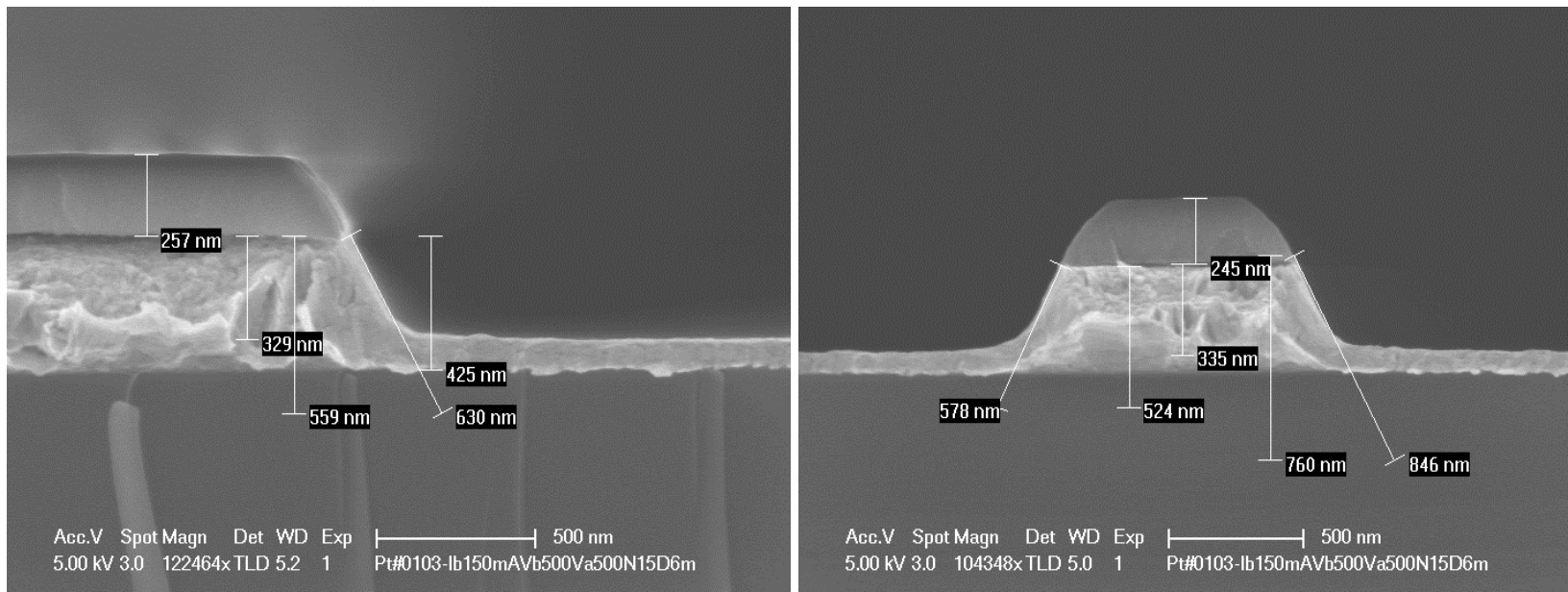


Figure 5 (a) and (b) Cross-section of the milled sample Pt04 with  $I_n=250\text{mA}$ ,  $P_{rf}=250\text{W}$ ,  $I_b=150\text{mA}$ ,  $V_b=500\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $-30^\circ$ , and time=6 minutes.

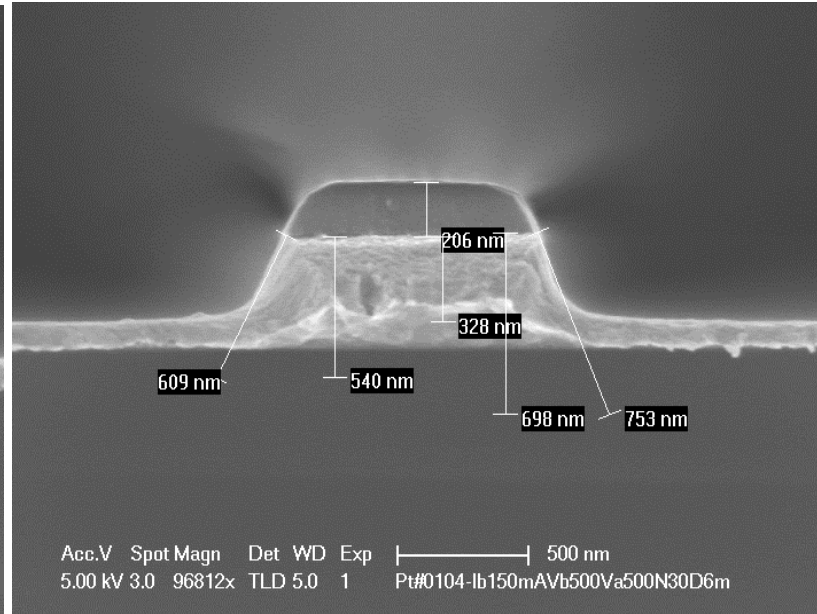
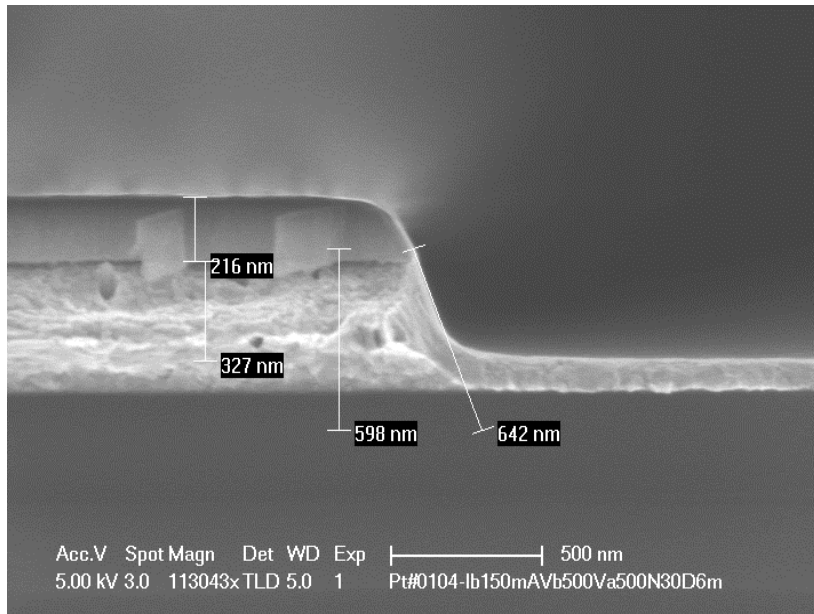


Figure 6 (a) and (b) Cross-section of the milled sample Pt05 with  $I_n=250\text{mA}$ ,  $P_{rf}=200\text{W}$ ,  $I_b=100\text{mA}$ ,  $V_b=500\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $-15^\circ$ , and time=9 minutes.

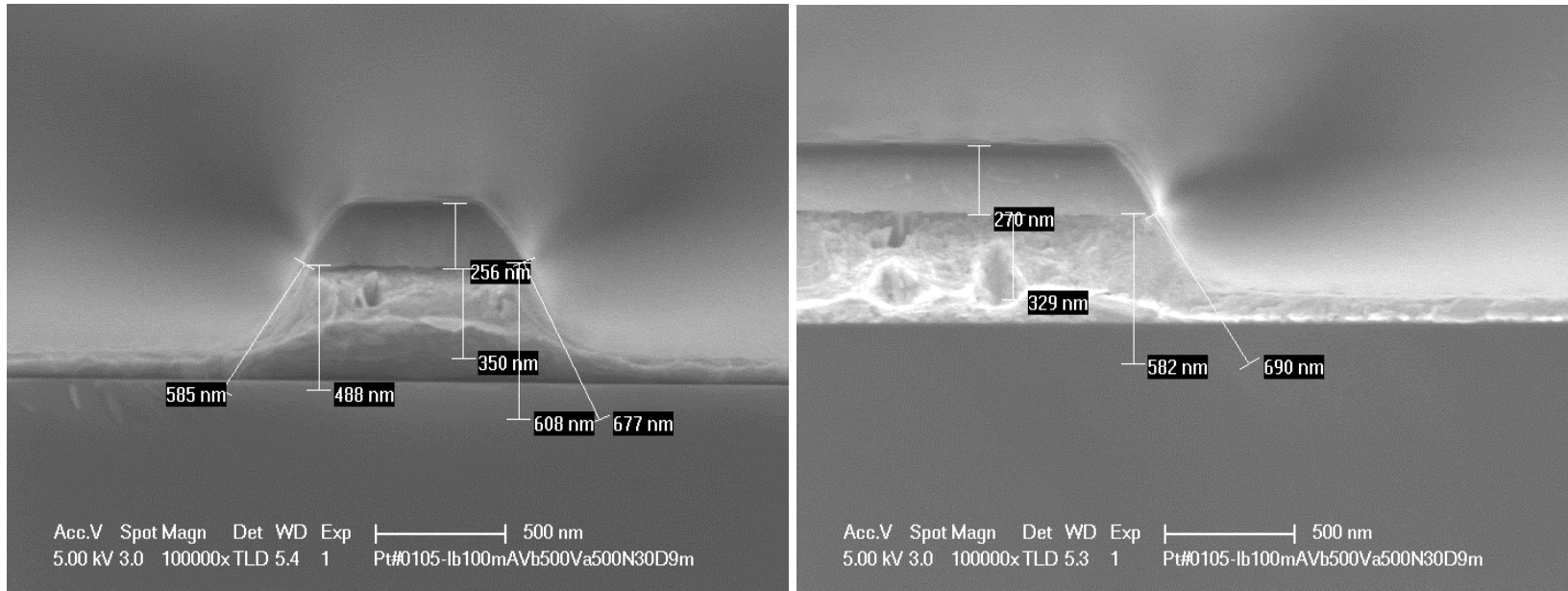




Figure 7 (a) and (b) Cross-section of the milled sample Pt06 with  $I_n=250\text{mA}$ ,  $P_{rf}=250\text{W}$ ,  $I_b=150\text{mA}$ ,  $V_b=500\text{V}$ ,  $V_a=250\text{V}$ , incident angle= $15^\circ$ , and time=6 minutes.

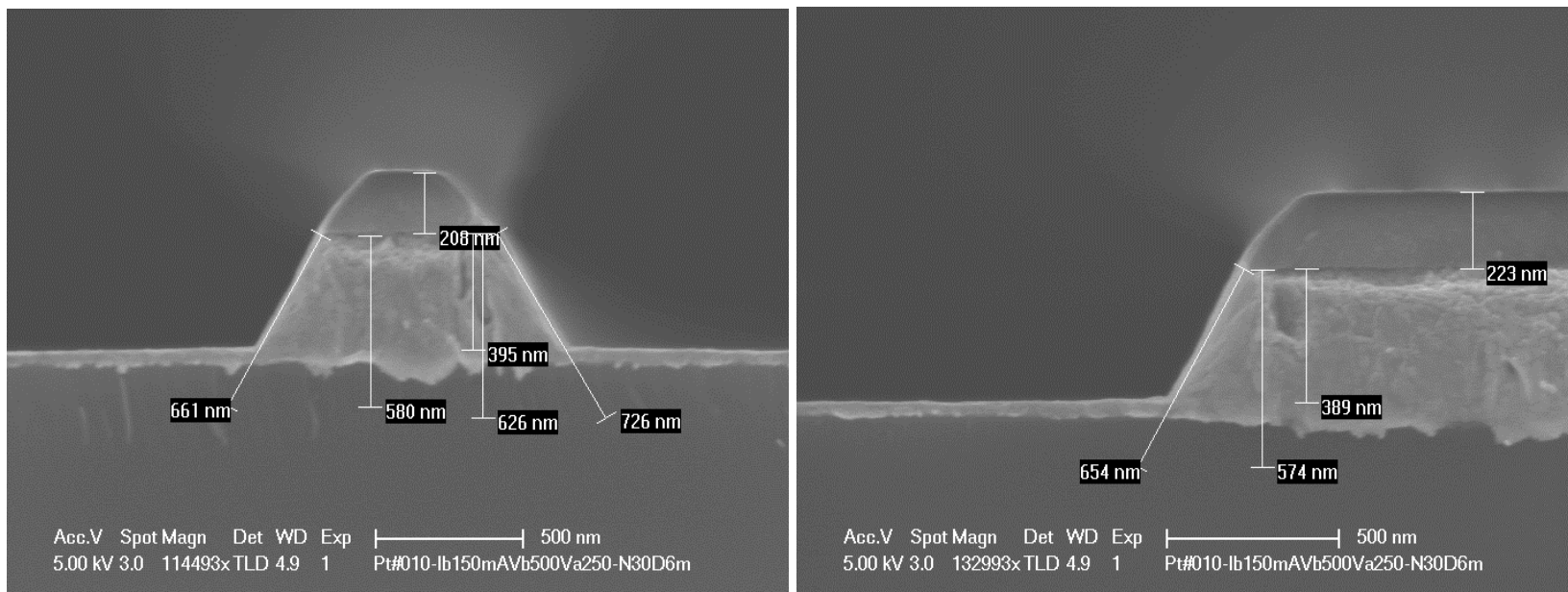


Figure 8 (a) and (b) Cross-section of the milled sample Pt07 with  $I_n=250\text{mA}$ ,  $P_{rf}=250\text{W}$ ,  $I_b=150\text{mA}$ ,  $V_b=500\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $30^\circ$ , and time=6 minutes.

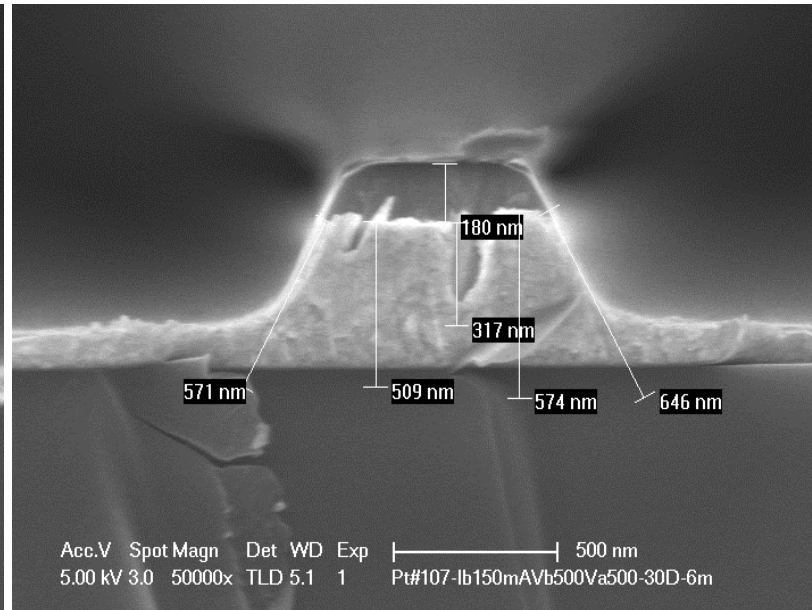
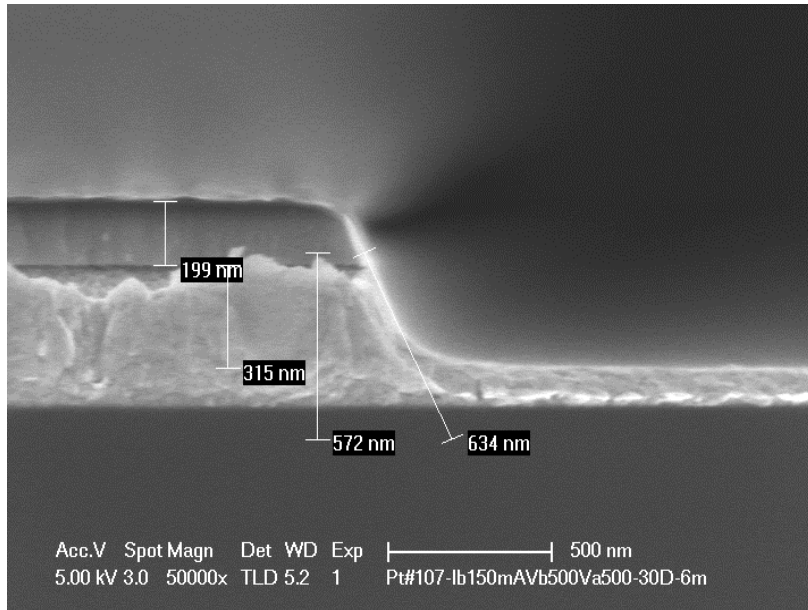


Figure 9 (a) and (b) Cross-section of the milled sample Pt08 with  $I_n=250\text{mA}$ ,  $P_{rf}=250\text{W}$ ,  $I_b=150\text{mA}$ ,  $V_b=500\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $45^\circ$ , and time=6 minutes.

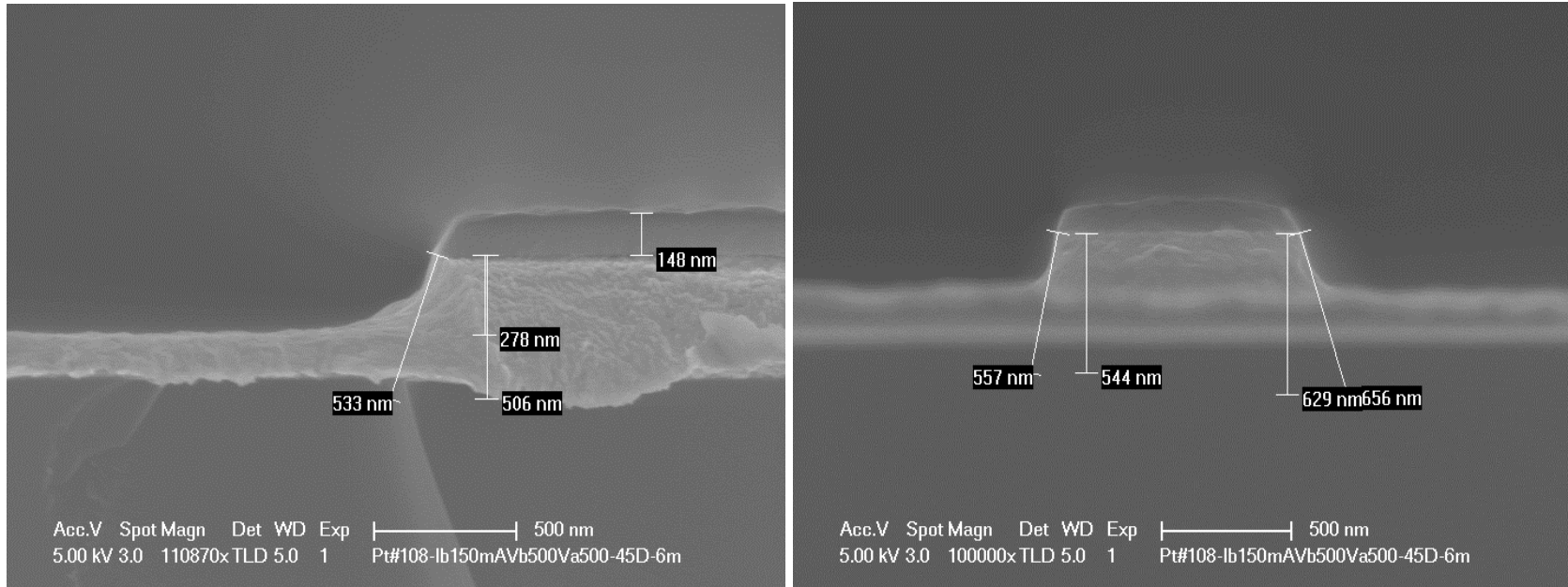


Figure 10 (a) and (b) Cross-section of the milled sample Pt10 with  $I_n=250\text{mA}$ ,  $P_{rf}=200\text{W}$ ,  $I_b=150\text{mA}$ ,  $V_b=250\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $-15^\circ$ , and time=8 minutes.

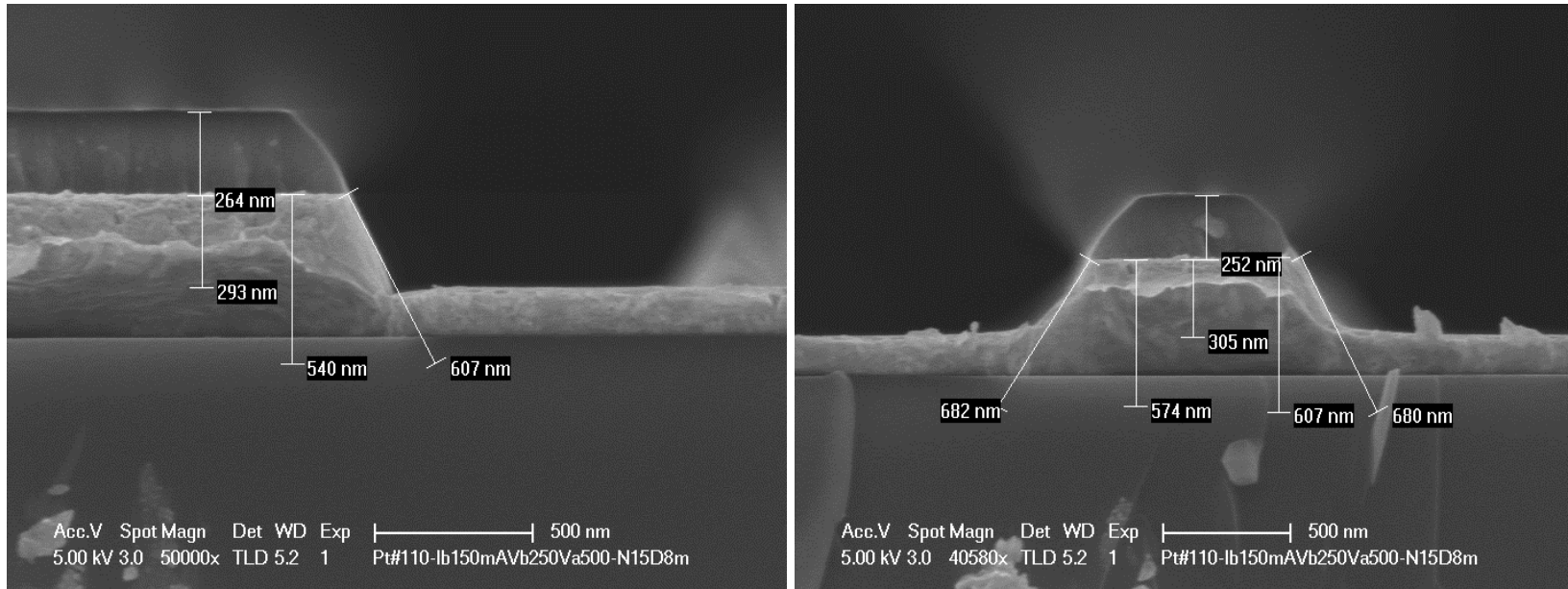


Figure 11 (a) and (b) Cross-section of the milled sample Pt12 with  $I_n=250\text{mA}$ ,  $P_{rf}=200\text{W}$ ,  $I_b=50\text{mA}$ ,  $V_b=250\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $-15^\circ$ , and time=25 minutes.

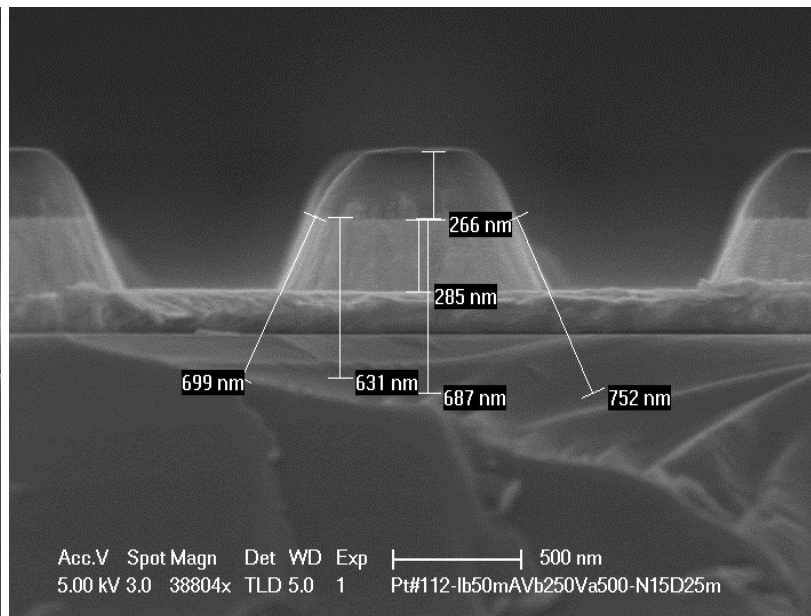
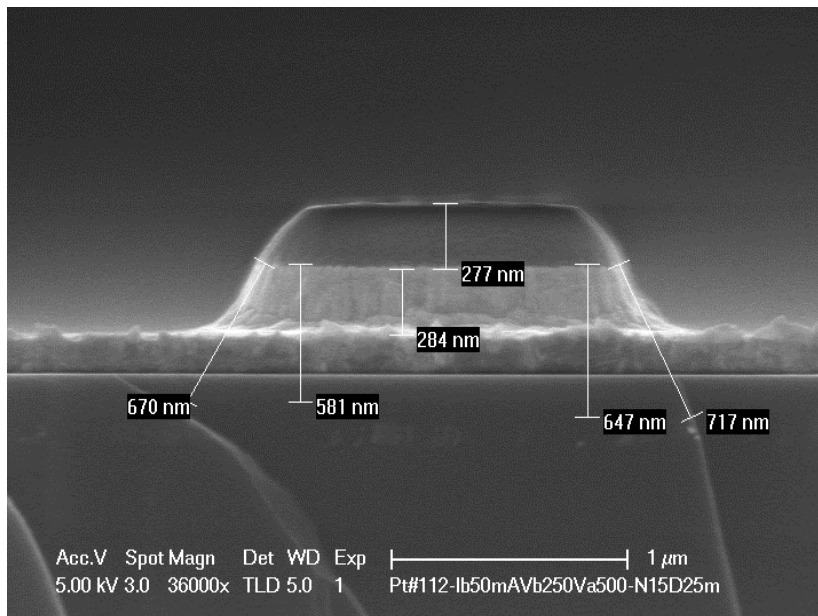


Figure 12 (a) and (b) Cross-section of the milled sample Pt13 with  $I_n=250\text{mA}$ ,  $P_{rf}=150\text{W}$ ,  $I_b=50\text{mA}$ ,  $V_b=500\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $-15^\circ$ , and time=20 minutes.

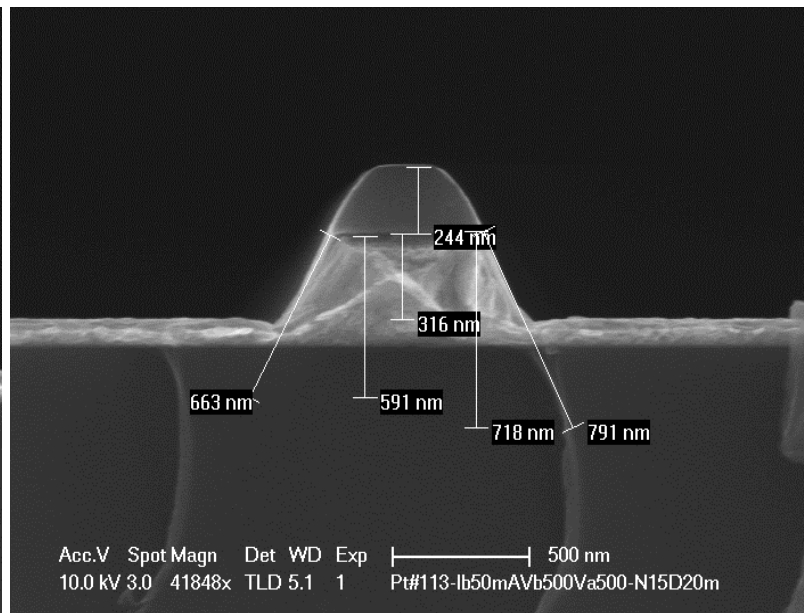
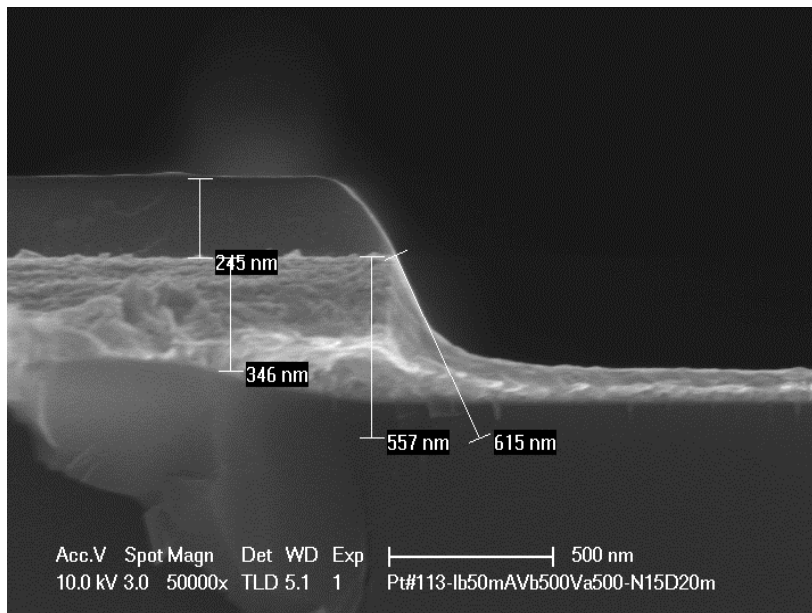


Figure 13 (a) and (b) Cross-section of the milled sample Pt14 with  $I_n=250\text{mA}$ ,  $P_{rf}=200\text{W}$ ,  $I_b=100\text{mA}$ ,  $V_b=250\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $-15^\circ$ , and time=15 minutes.

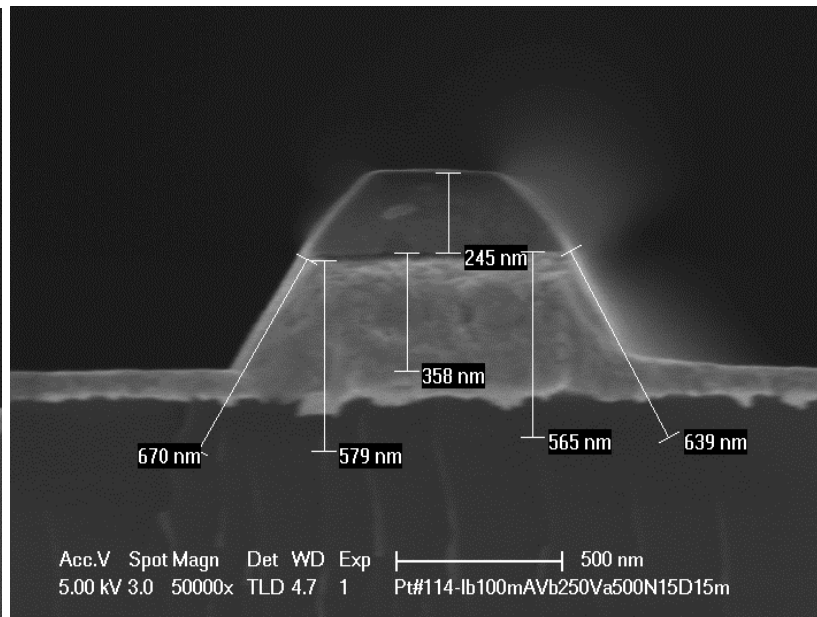
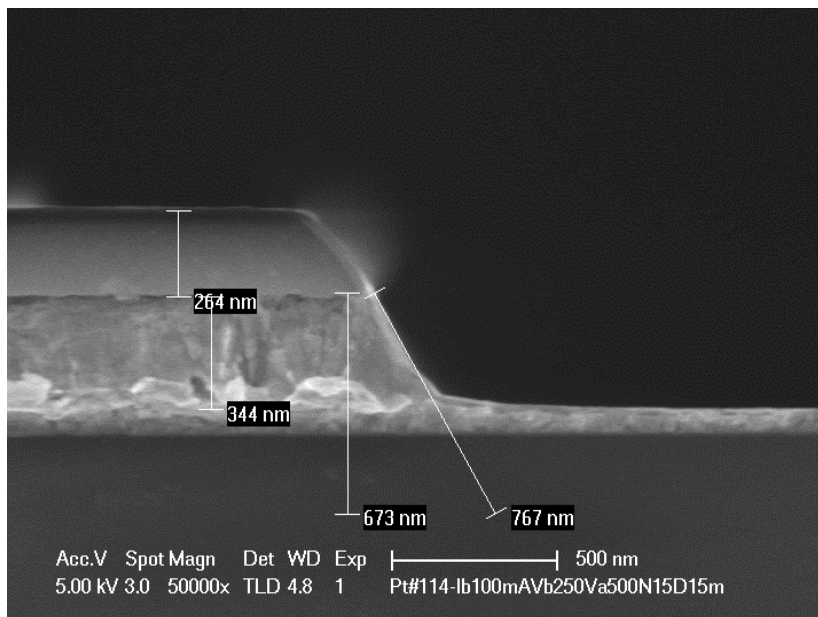


Figure 14 (a) and (b) Cross-section of the milled sample Pt15 with  $I_n=250\text{mA}$ ,  $P_{rf}=150\text{W}$ ,  $I_b=50\text{mA}$ ,  $V_b=125\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $-15^\circ$ , and time=50 minutes.

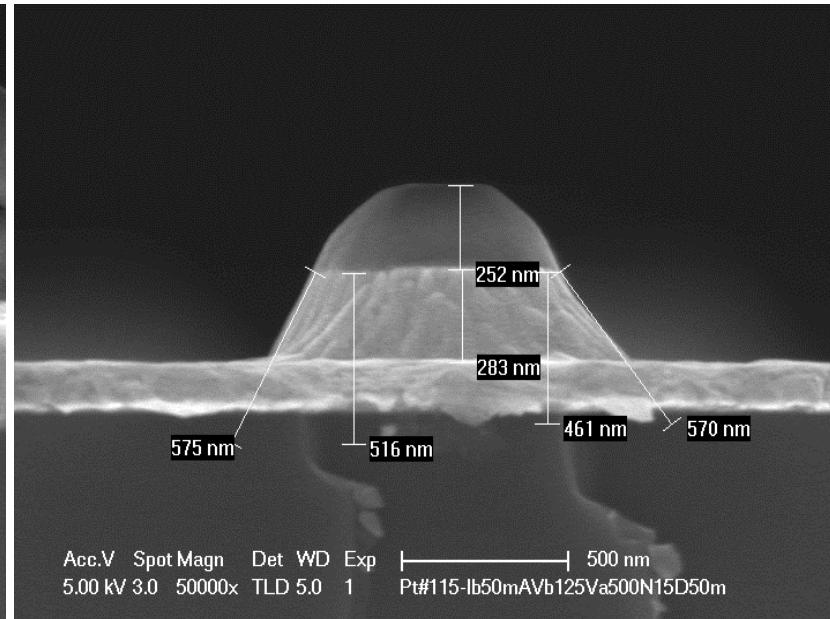
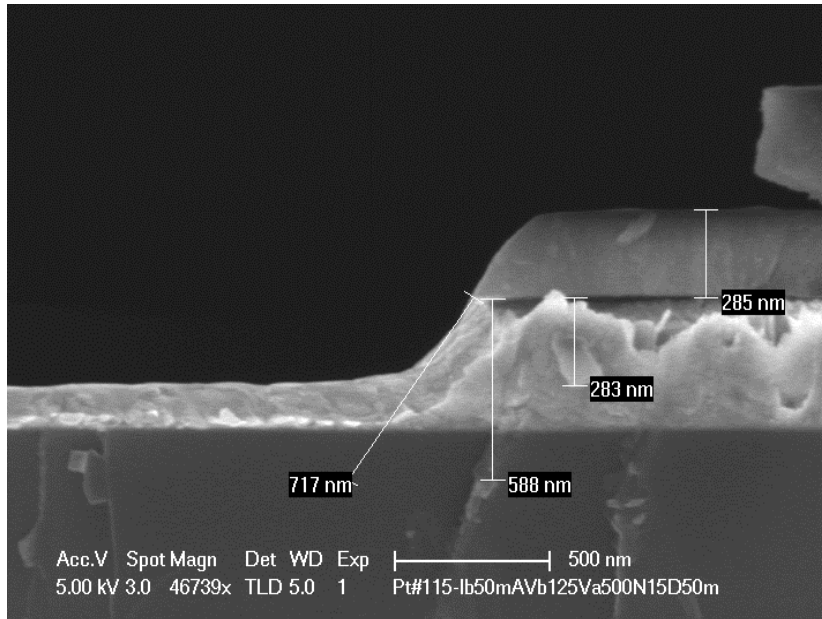




Figure 15 (a) and (b) Cross-section of the milled sample Pt16 with  $I_n=250\text{mA}$ ,  $P_{rf}=150\text{W}$ ,  $I_b=25\text{mA}$ ,  $V_b=250\text{V}$ ,  $V_a=500\text{V}$ , incident angle= $-15^\circ$ , and time=50 minutes.

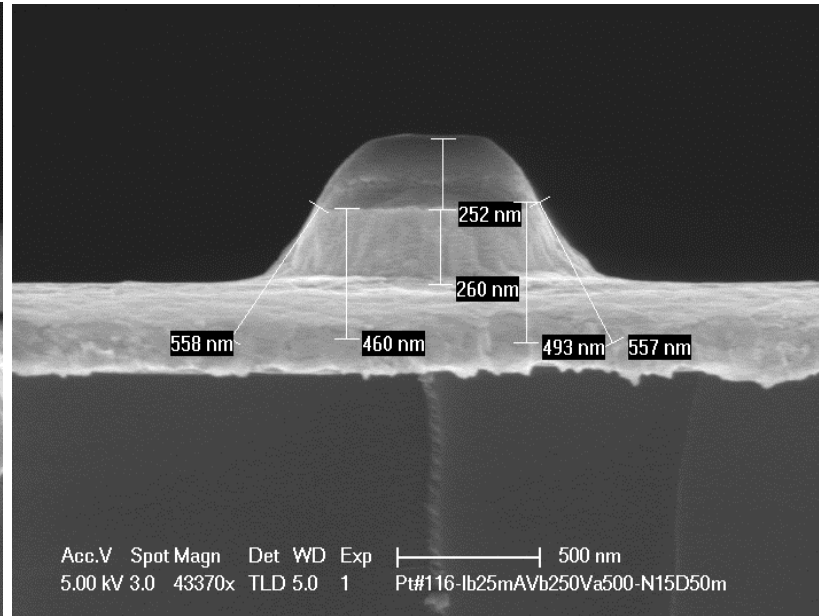
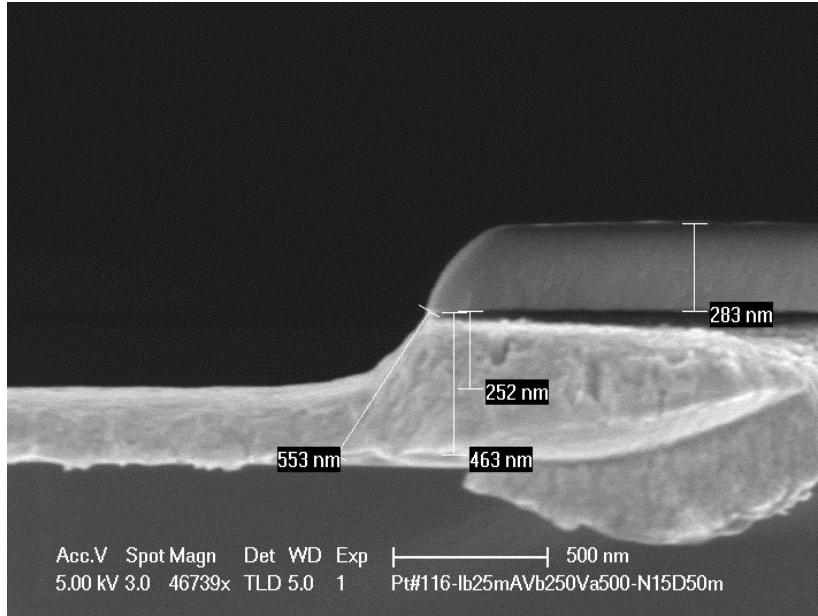


Figure 16 Platinum etch rate and selectivity (Pt/Al<sub>2</sub>O<sub>3</sub>) as functions of Ar-ion incident angle.

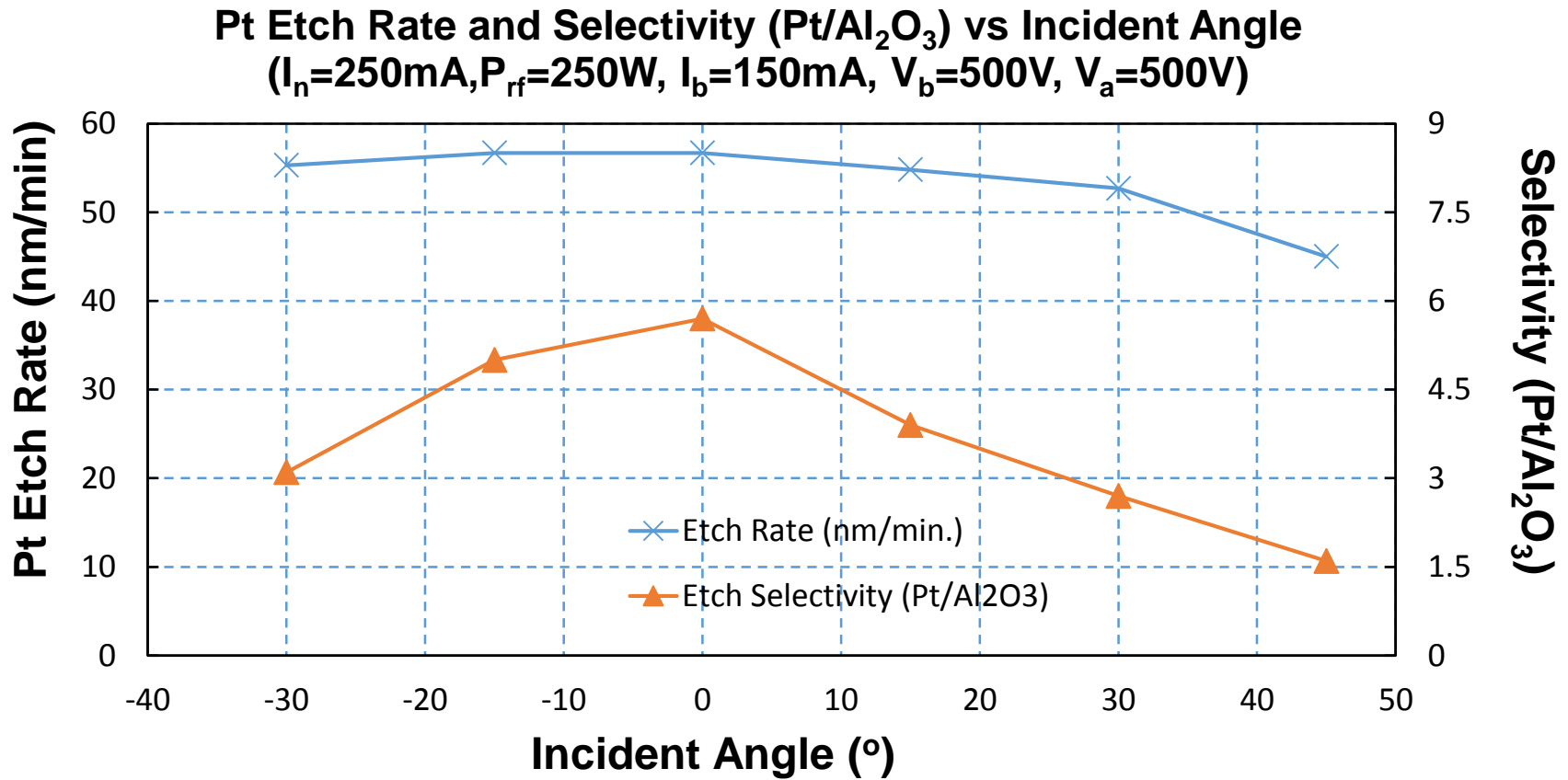


Figure 17 Sidewall angle of etched platinum as a function of Ar-ion incident angle.

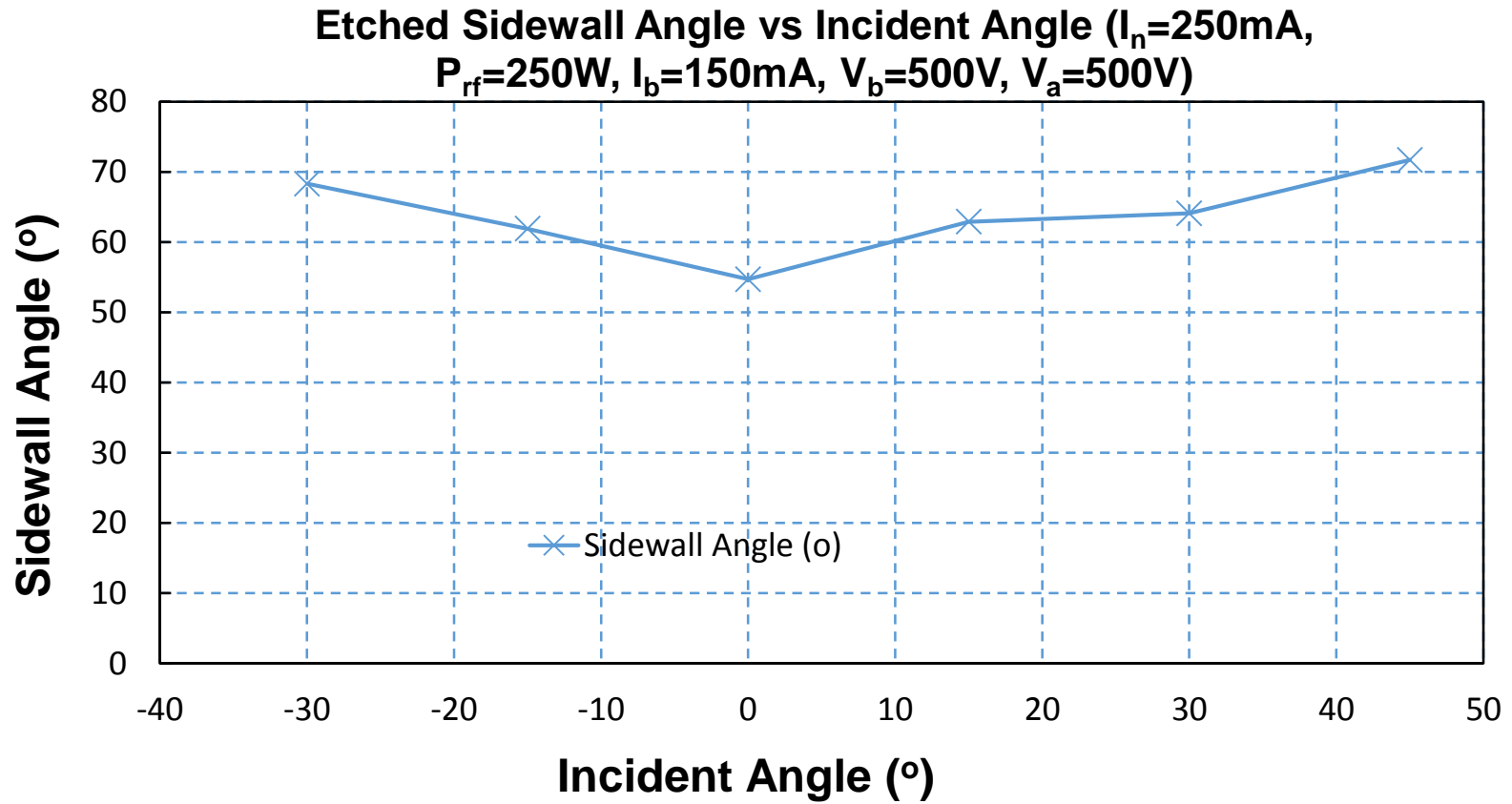


Figure 18 Platinum etch rate and selectivity (Pt/Al<sub>2</sub>O<sub>3</sub>) as functions of Ar-ion beam current at a beam voltage of 500 V.

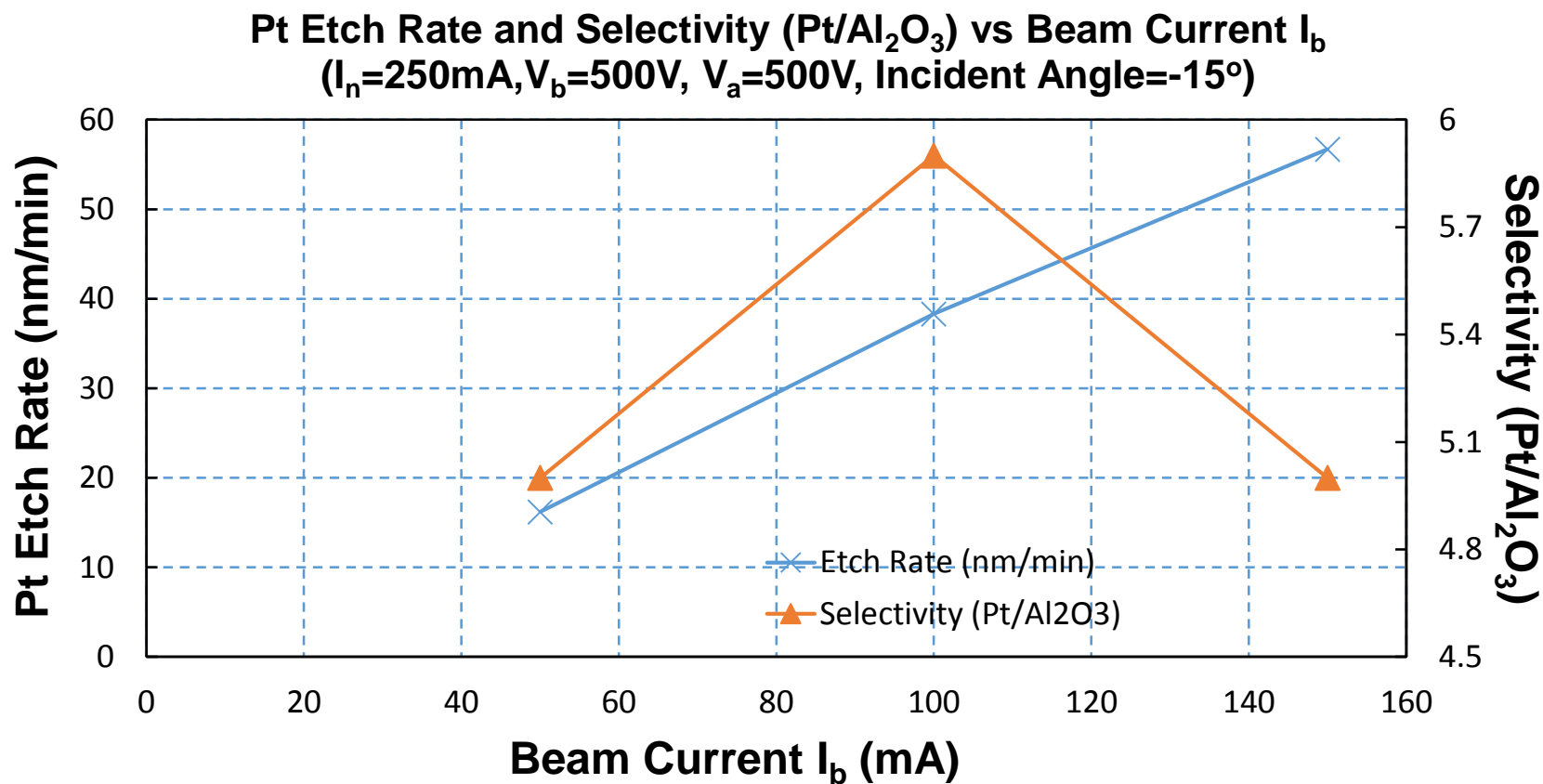


Figure 19 Sidewall angle of etched platinum as a function of Ar-ion beam current at a beam voltage of 500 V.

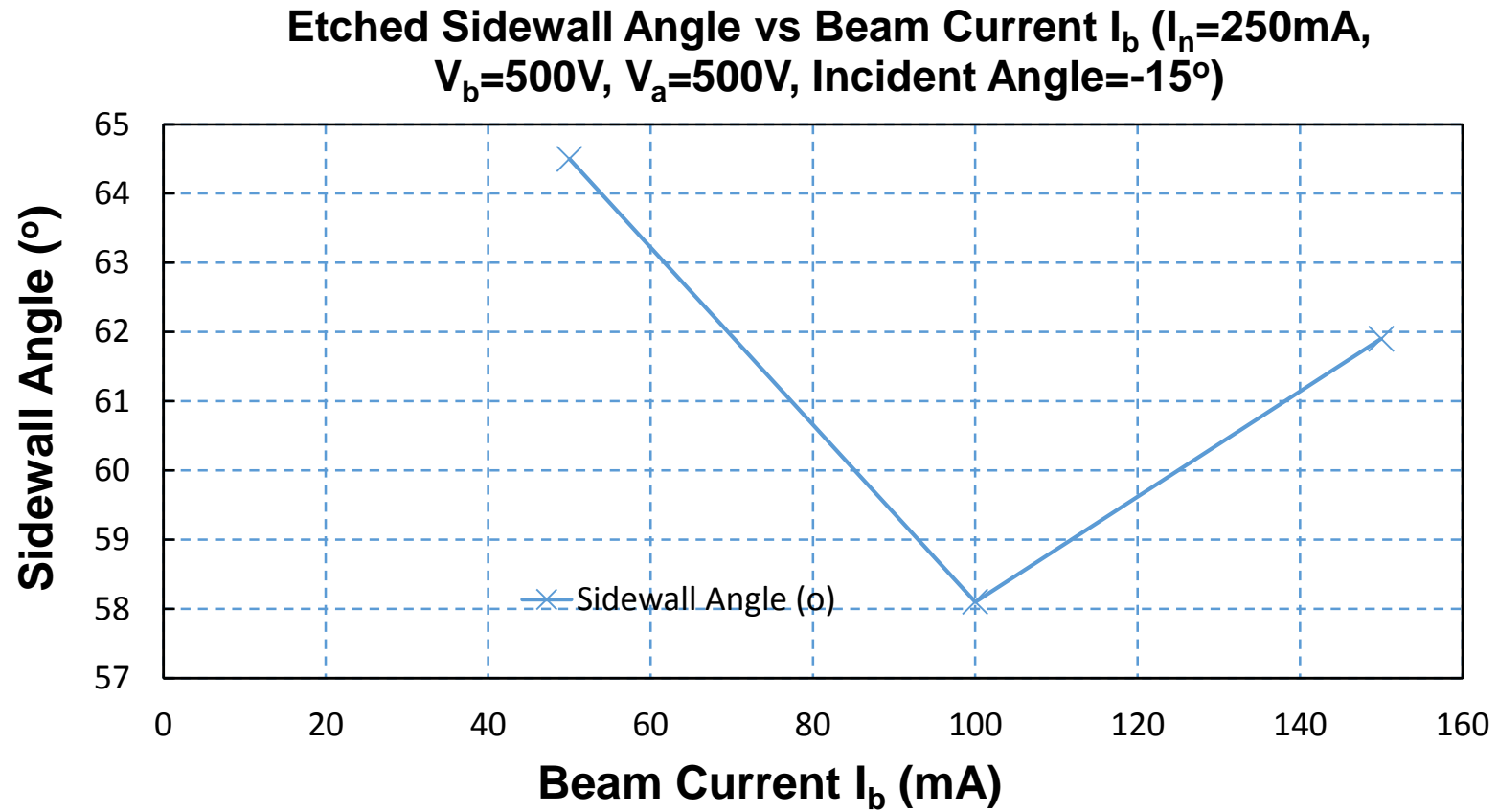


Figure 20 Platinum etch rate and selectivity (Pt/Al<sub>2</sub>O<sub>3</sub>) as functions of Ar-ion beam current at a beam voltage of 250 V.

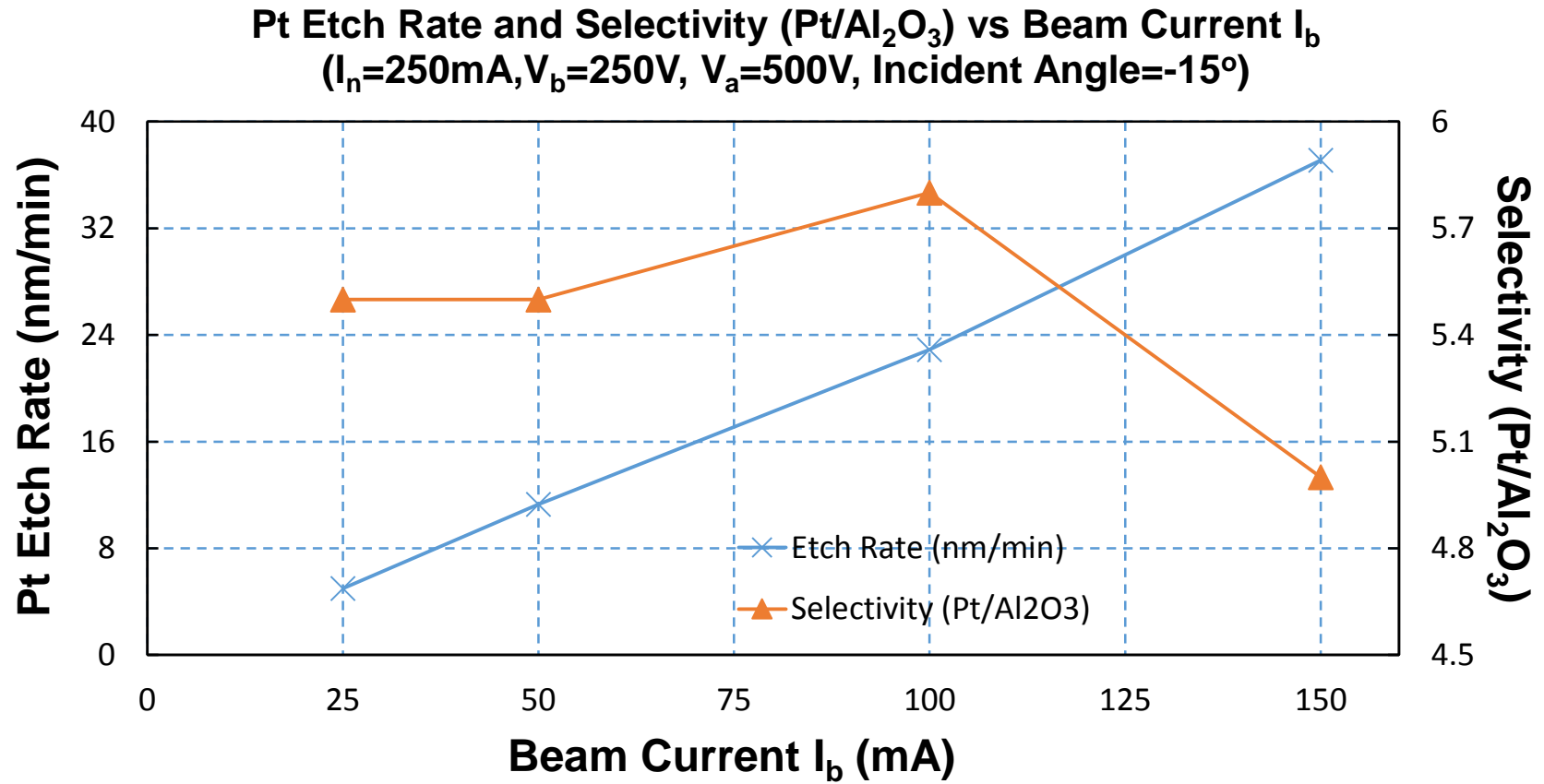


Figure 21 Sidewall angle of etched platinum as a function of Ar-ion beam current at a beam voltage of 250 V.

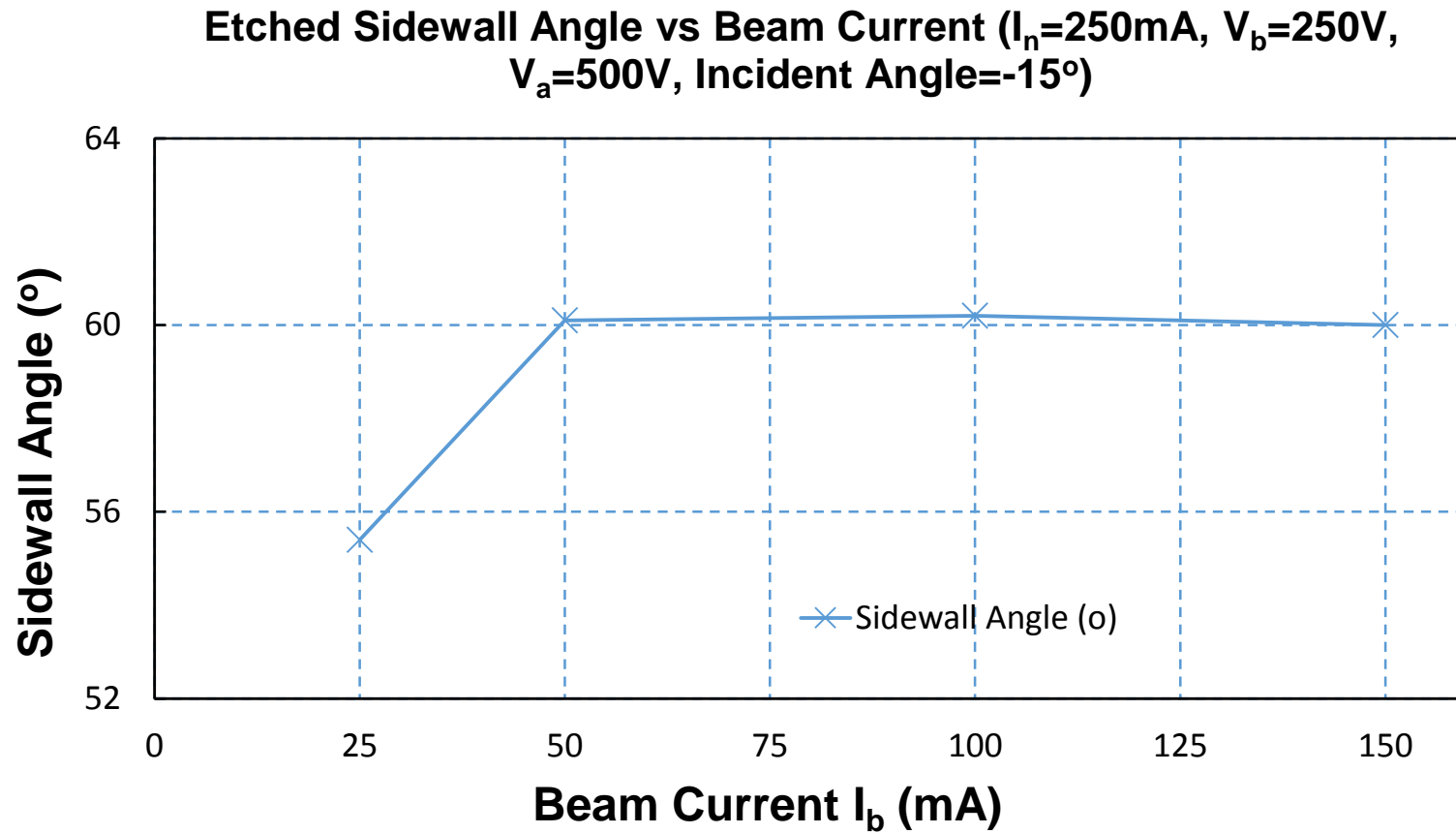


Figure 22 Platinum etch rate and selectivity (Pt/Al<sub>2</sub>O<sub>3</sub>) as functions of Ar-ion beam voltage at a beam current of 50 mA.

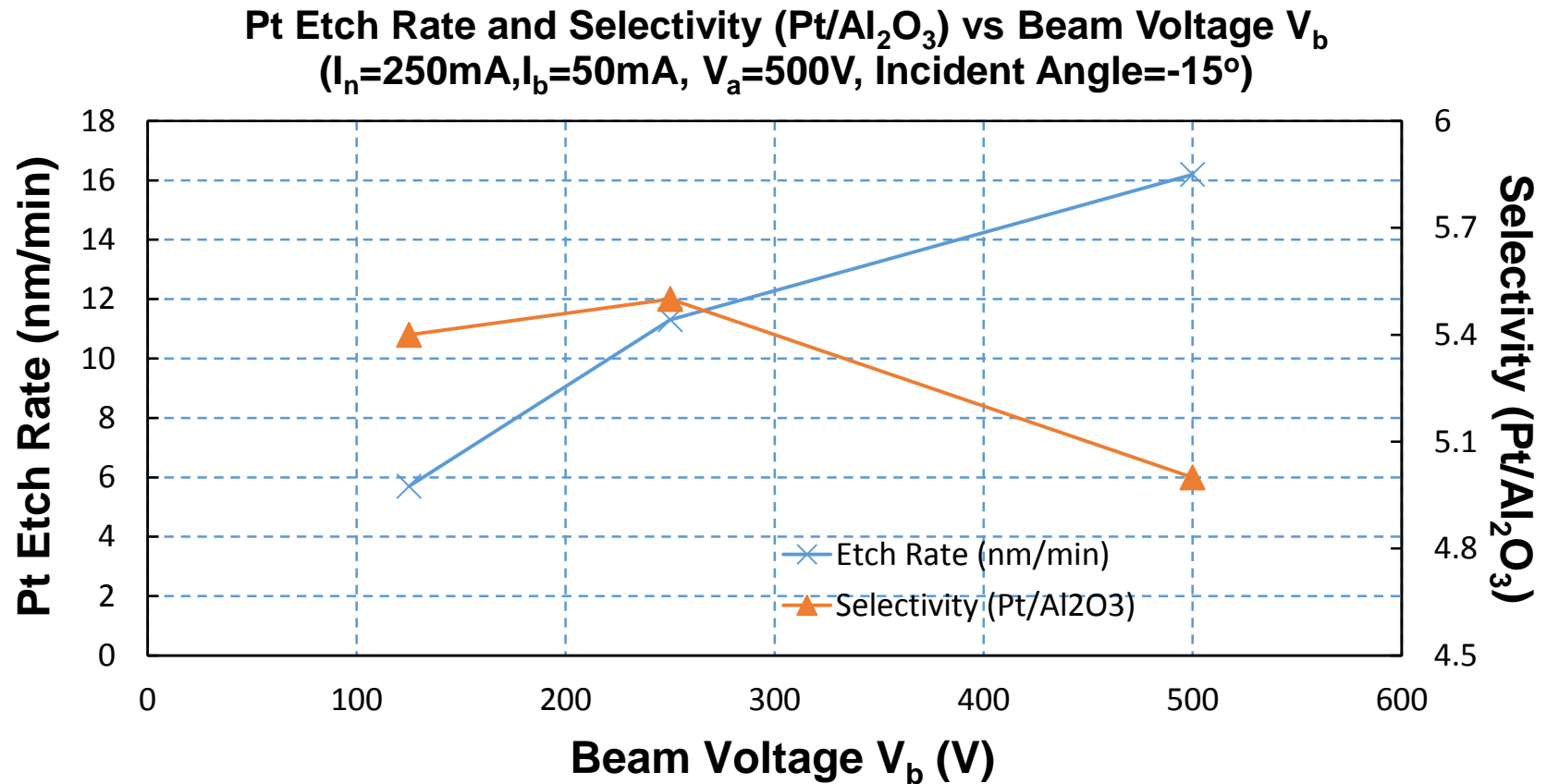




Figure 23 Sidewall angle of etched platinum as a function of Ar-ion beam voltage at a beam current of 50 mA.

