Etching Platinum using Oxford Ion Mill Tool

Object: To get the etch rate and selectivity (Al_2O_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) O_2 plasma descum 300mT/100W 60 s.

4) **Depositing** Al_2O_3 (target thickness: 350.3 nm, actual thickness: 305 nm, Tooling factor: 305.3*171.1/350=149.2) using E-beam#2.

5) **Lifting-off Al_2O_3**: a) soaking in 1165 striper 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_2O_3), 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_2O_3)	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_2O_3 mask pattern before ion-mill.

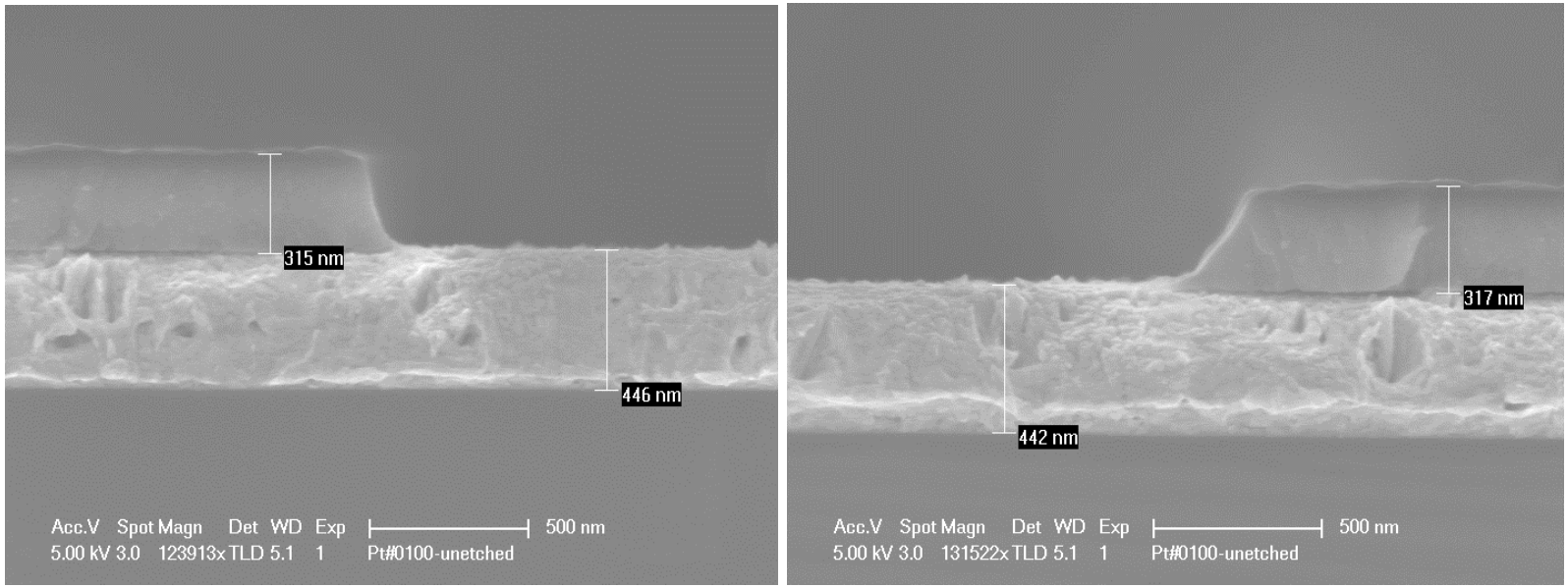


Figure 2 (a) and (b) Cross-section of the milled sample Pt01 with I_n=250mA, P_{rf}=250W, I_b=150mA, V_b=500V, V_a=500V, incident angle=0^o, and time=6 minutes.

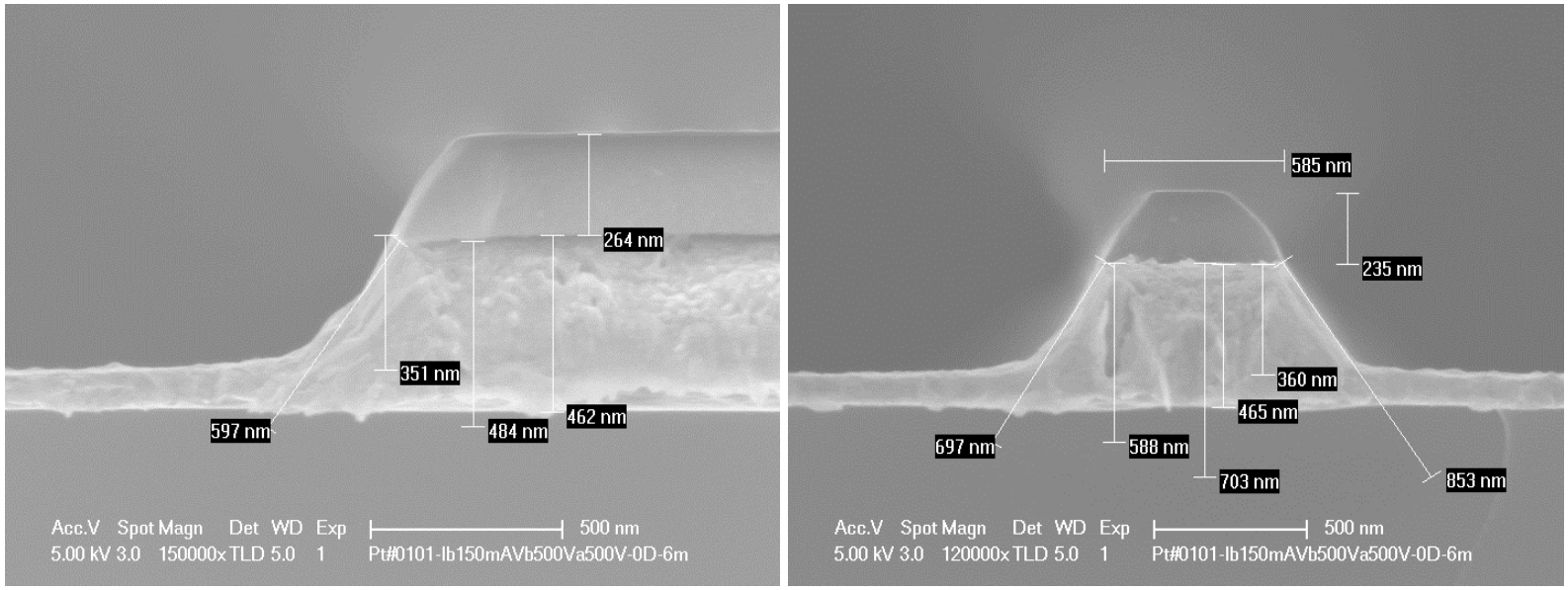


Figure 3 (a) and (b) Cross-section of the milled sample Pt02 with I_n=250mA, P_{rf}=250W, I_b=150mA, V_b=500V, V_a=500V, incident angle=15^o, and time=6 minutes.

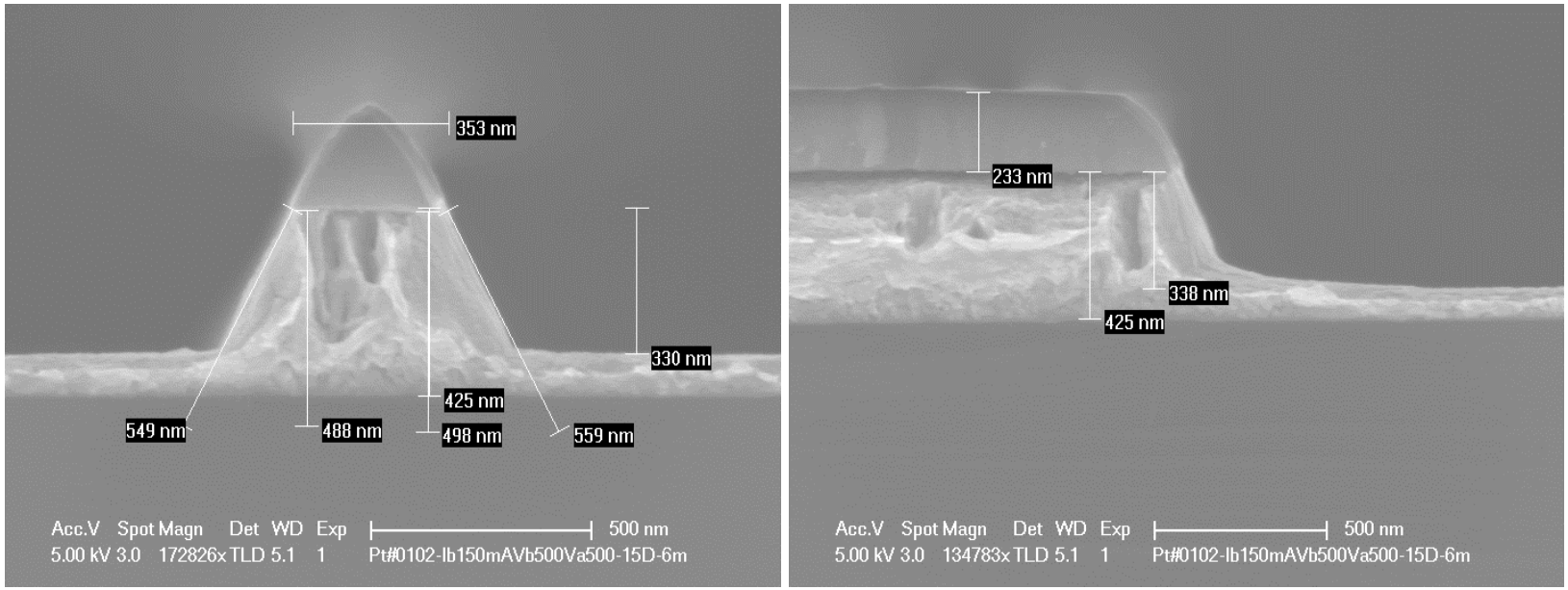


Figure 4 (a) and (b) Cross-section of the milled sample Pt03 with I_n=250mA, P_{rf}=250W, I_b=150mA, V_b=500V, V_a=500V, incident angle=-15^o, and time=6 minutes.

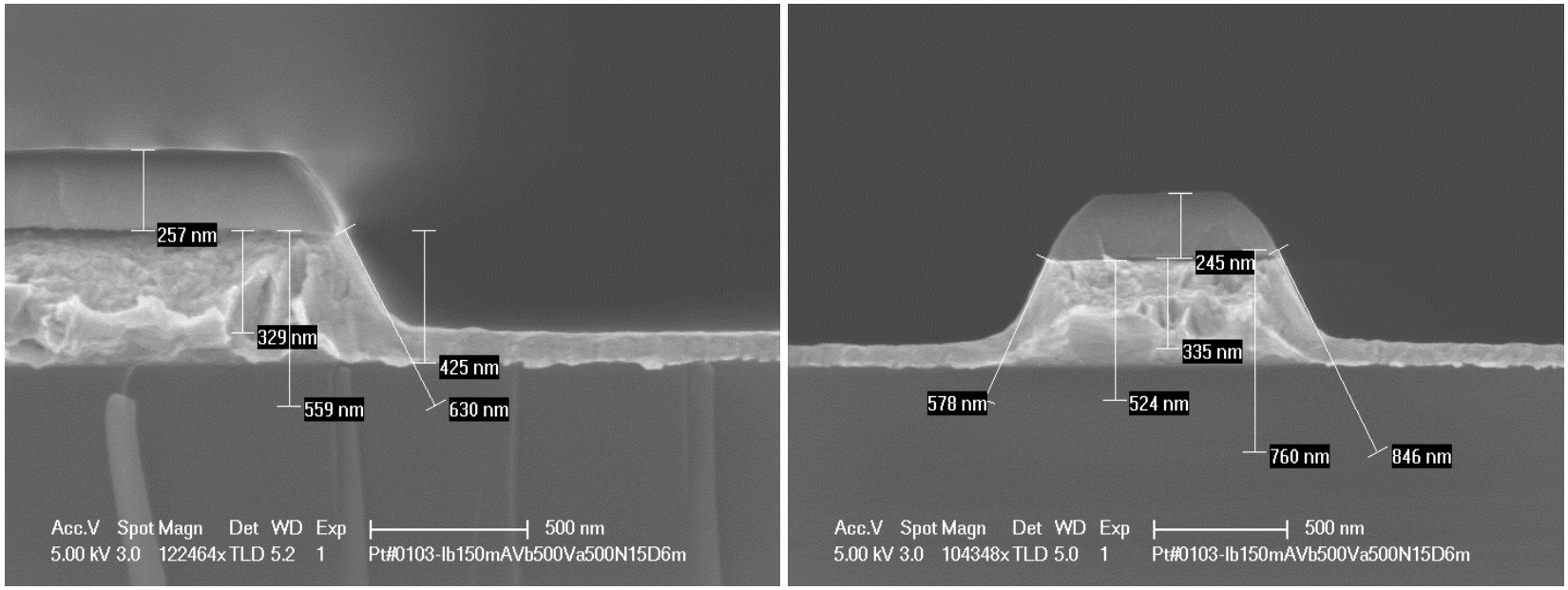


Figure 5 (a) and (b) Cross-section of the milled sample Pt04 with I_n=250mA, P_{rf}=250W, I_b=150mA, V_b=500V, V_a=500V, incident angle=-30^o, and time=6 minutes.

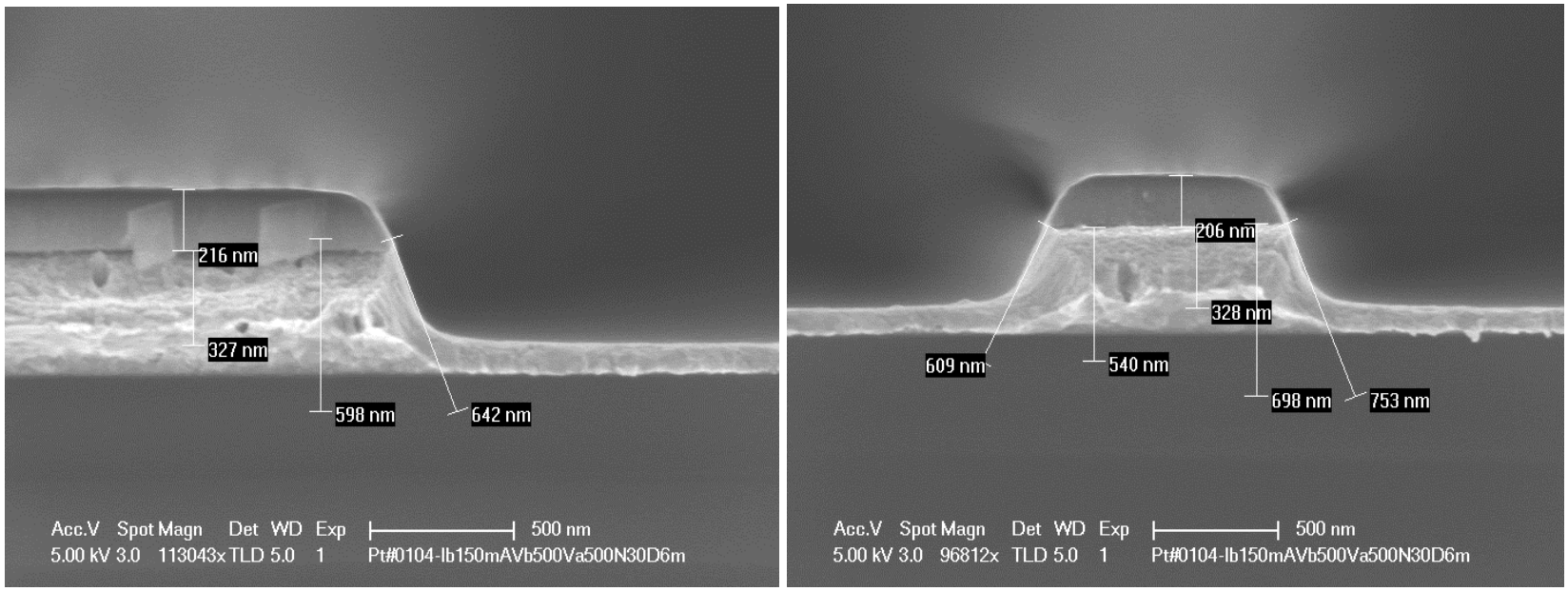


Figure 6 (a) and (b) Cross-section of the milled sample Pt05 with I_n=250mA, P_{rf}=200W, I_b=100mA, V_b=500V, V_a=500V, incident angle=-15^o, and time=9 minutes.

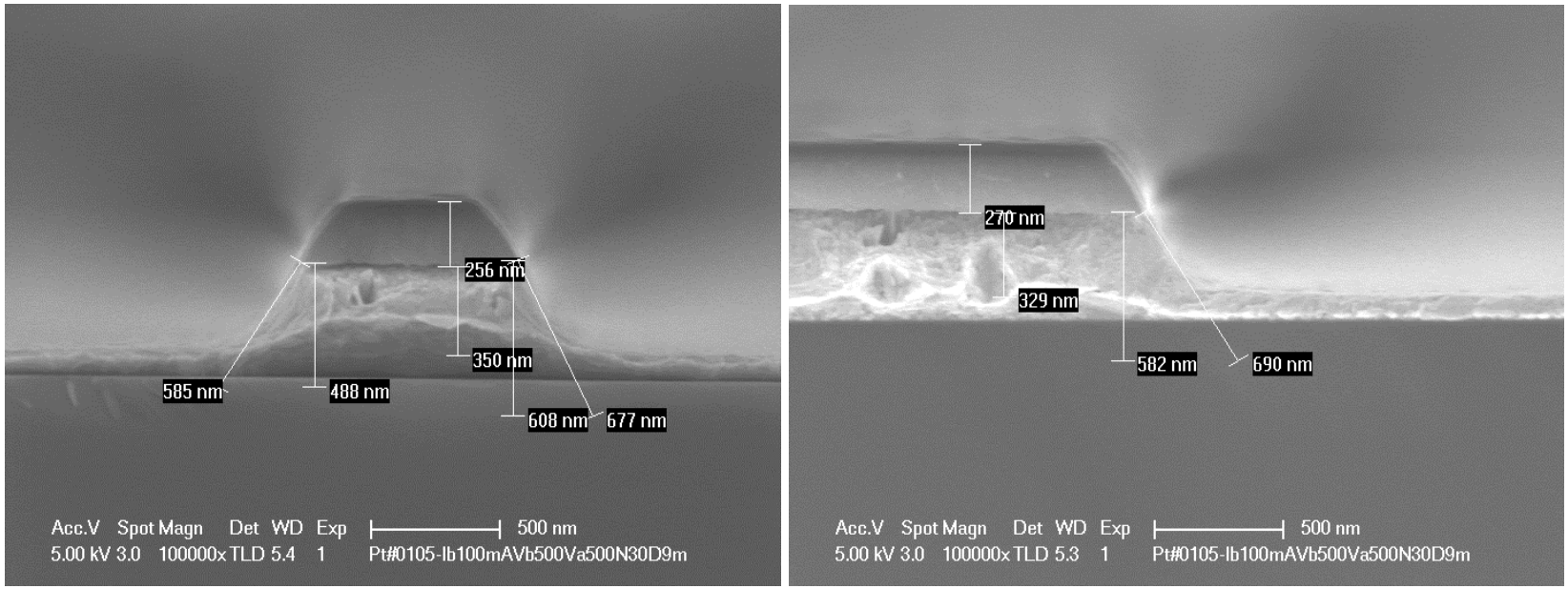


Figure 7 (a) and (b) Cross-section of the milled sample Pt06 with I_n=250mA, P_{rf}=250W, I_b=150mA, V_b=500V, V_a=250V, incident angle=15^o, and time=6 minutes.

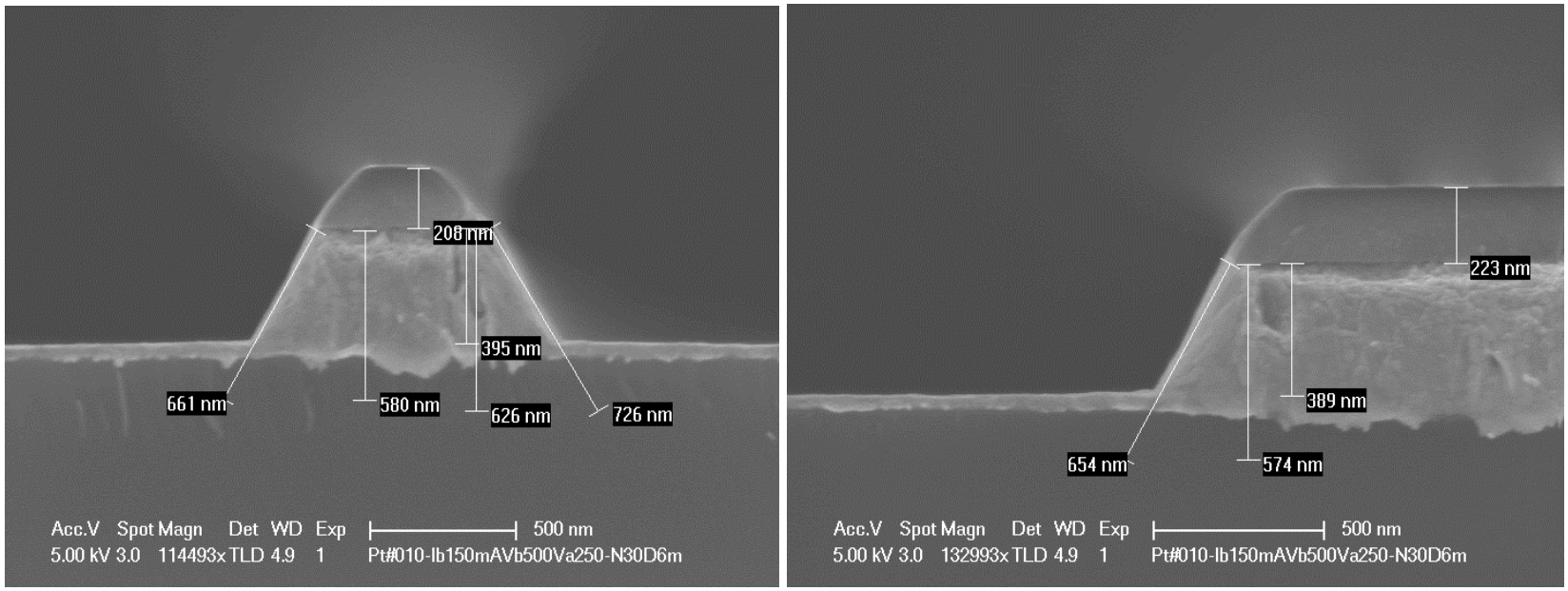


Figure 8 (a) and (b) Cross-section of the milled sample Pt07 with I_n=250mA, P_{rf}=250W, I_b=150mA, V_b=500V, V_a=500V, incident angle=30^o, and time=6 minutes.

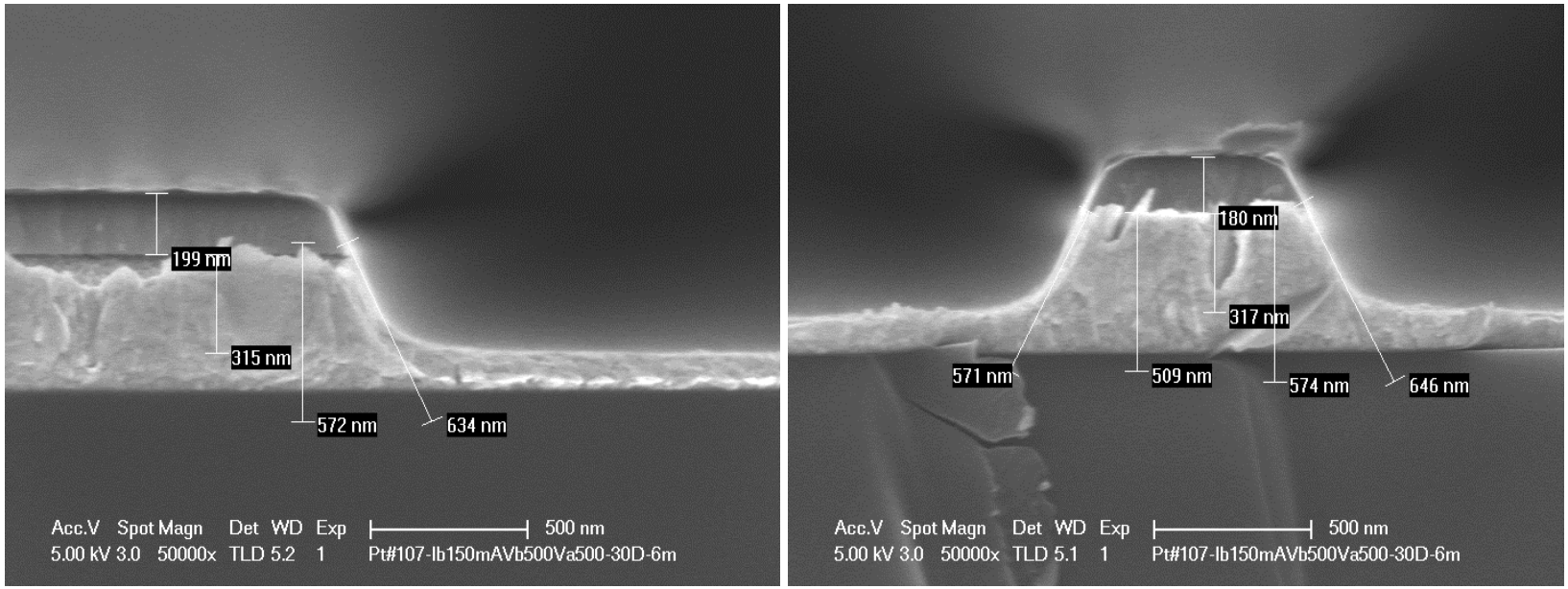
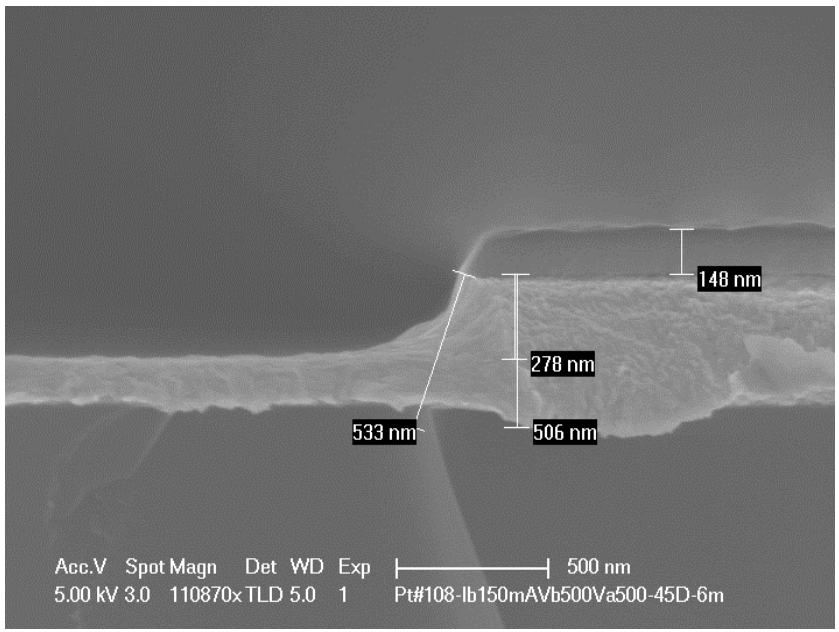


Figure 9 (a) and (b) Cross-section of the milled sample Pt08 with I_n=250mA, P_{rf}=250W, I_b=150mA, V_b=500V, V_a=500V, incident angle=45^o, and time=6 minutes.



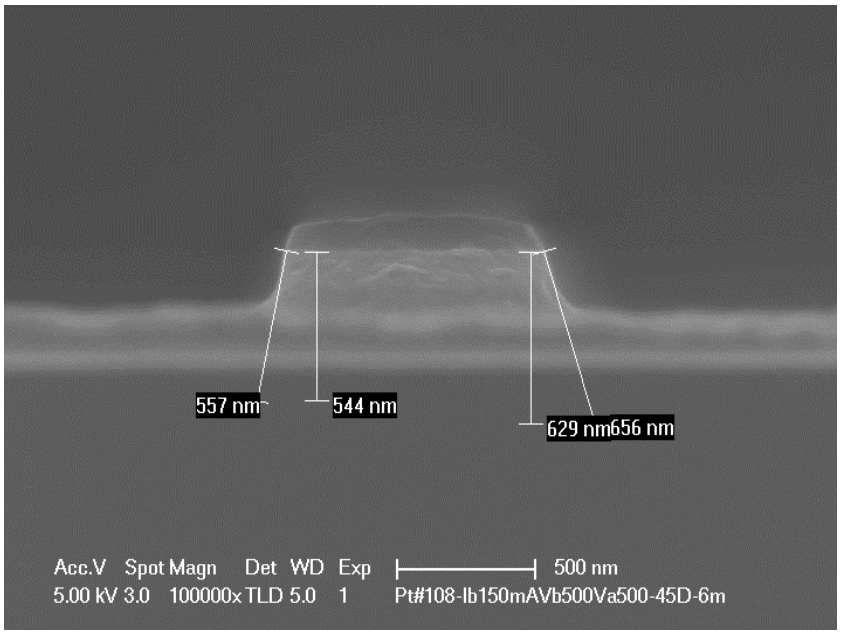


Figure 10 (a) and (b) Cross-section of the milled sample Pt10 with I_n=250mA, P_{rf}=200W, I_b=150mA, V_b=250V, V_a=500V, incident angle=-15^o, and time=8 minutes.

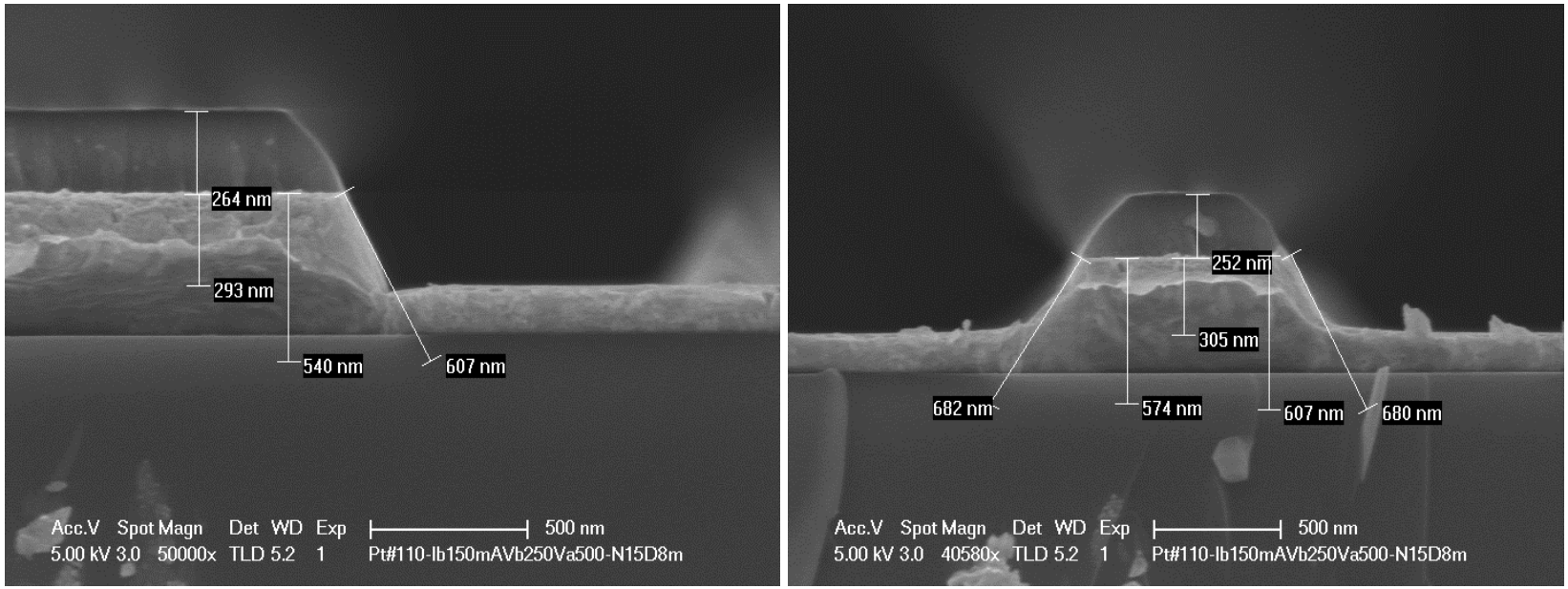
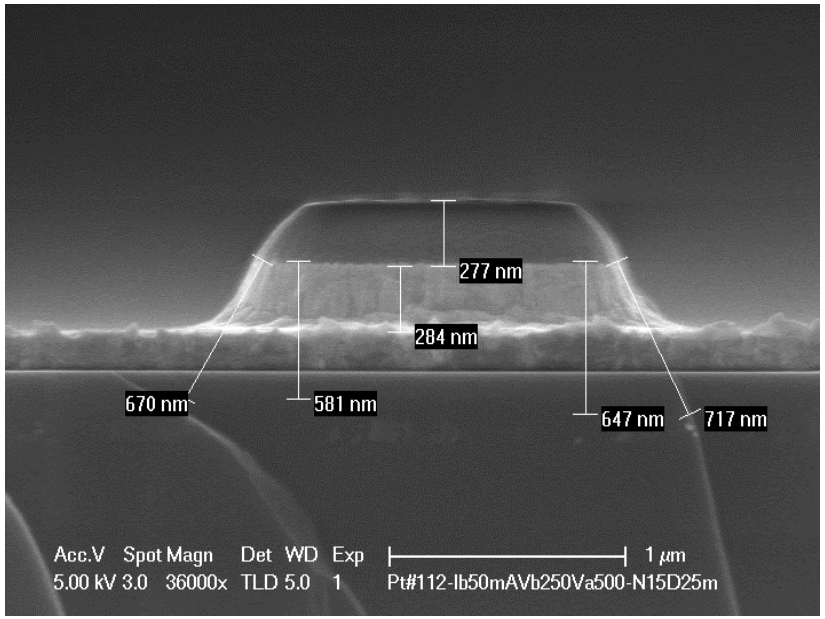


Figure 11 (a) and (b) Cross-section of the milled sample Pt12 with I_n=250mA, P_{rf}=200W, I_b=50mA, V_b=250V, V_a=500V, incident angle=-15^o, and time=25 minutes.



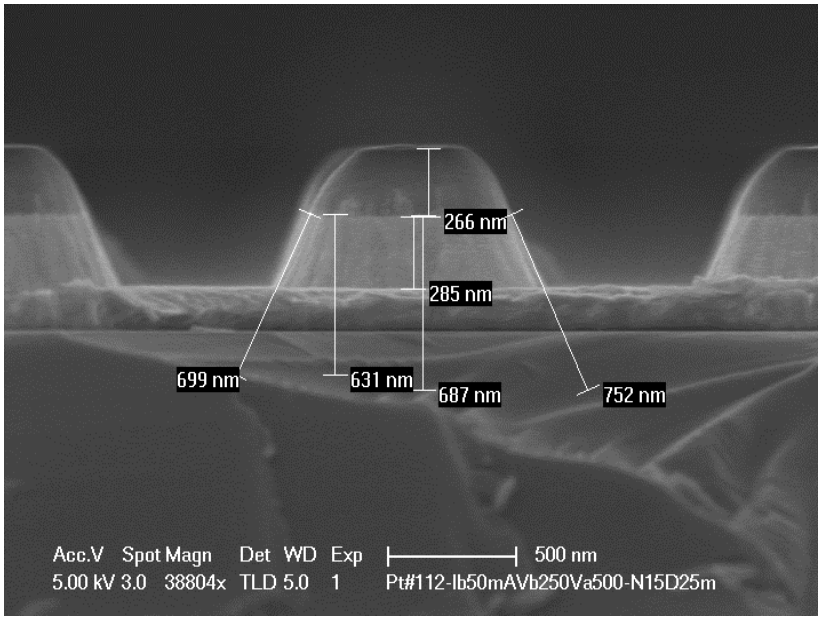


Figure 12 (a) and (b) Cross-section of the milled sample Pt13 with I_n=250mA, P_{rf}=150W, I_b=50mA, V_b=500V, V_a=500V, incident angle=-15^o, and time=20 minutes.

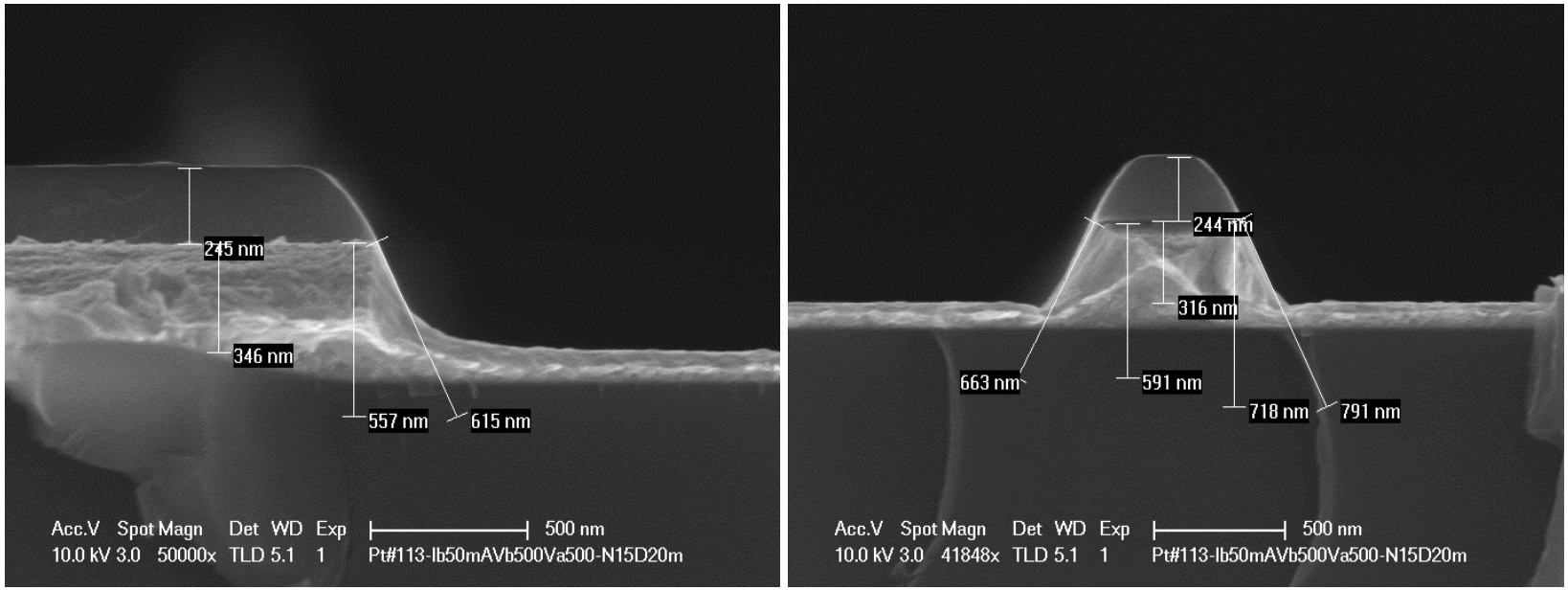
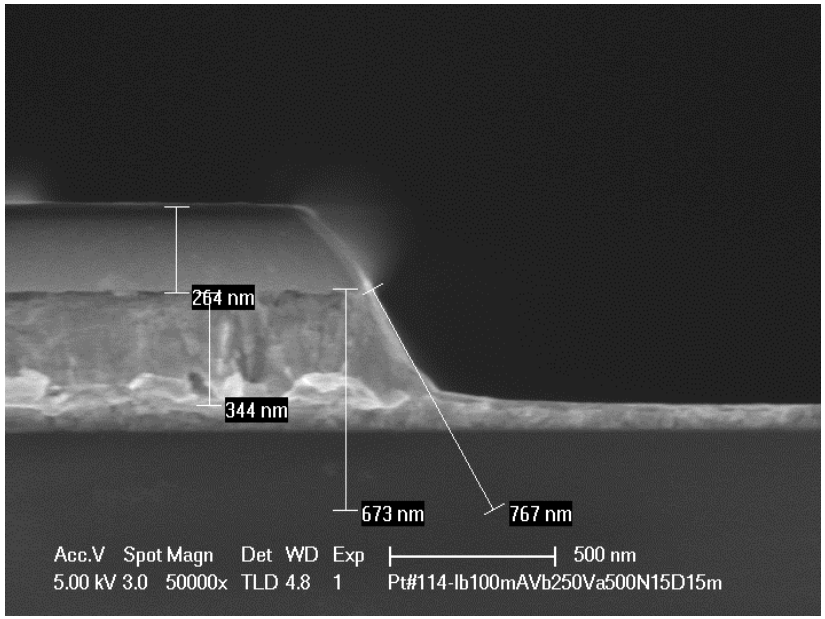


Figure 13 (a) and (b) Cross-section of the milled sample Pt14 with I_n=250mA, P_{rf}=200W, I_b=100mA, V_b=250V, V_a=500V, incident angle=-15^o, and time=15 minutes.



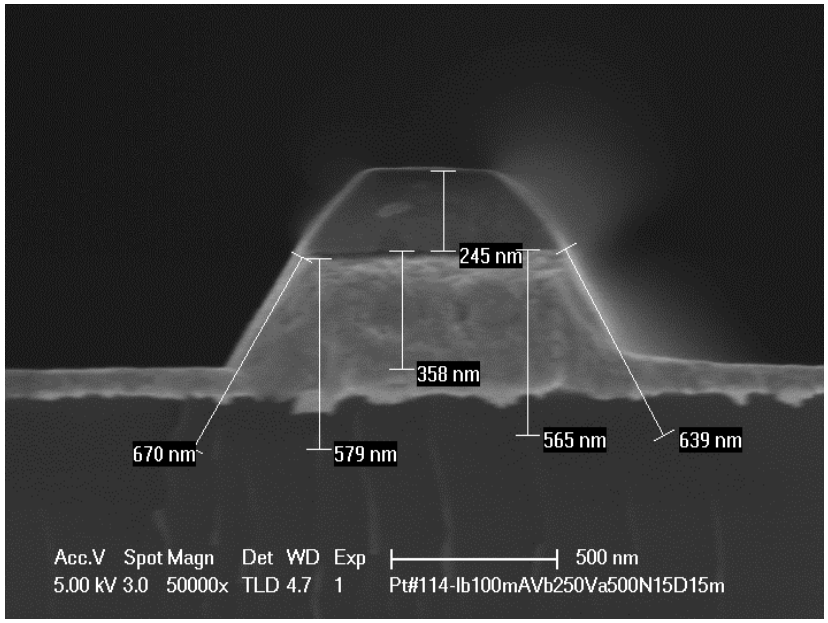


Figure 14 (a) and (b) Cross-section of the milled sample Pt15 with I_n=250mA, P_{rf}=150W, I_b=50mA, V_b=125V, V_a=500V, incident angle=-15^o, and time=50 minutes.

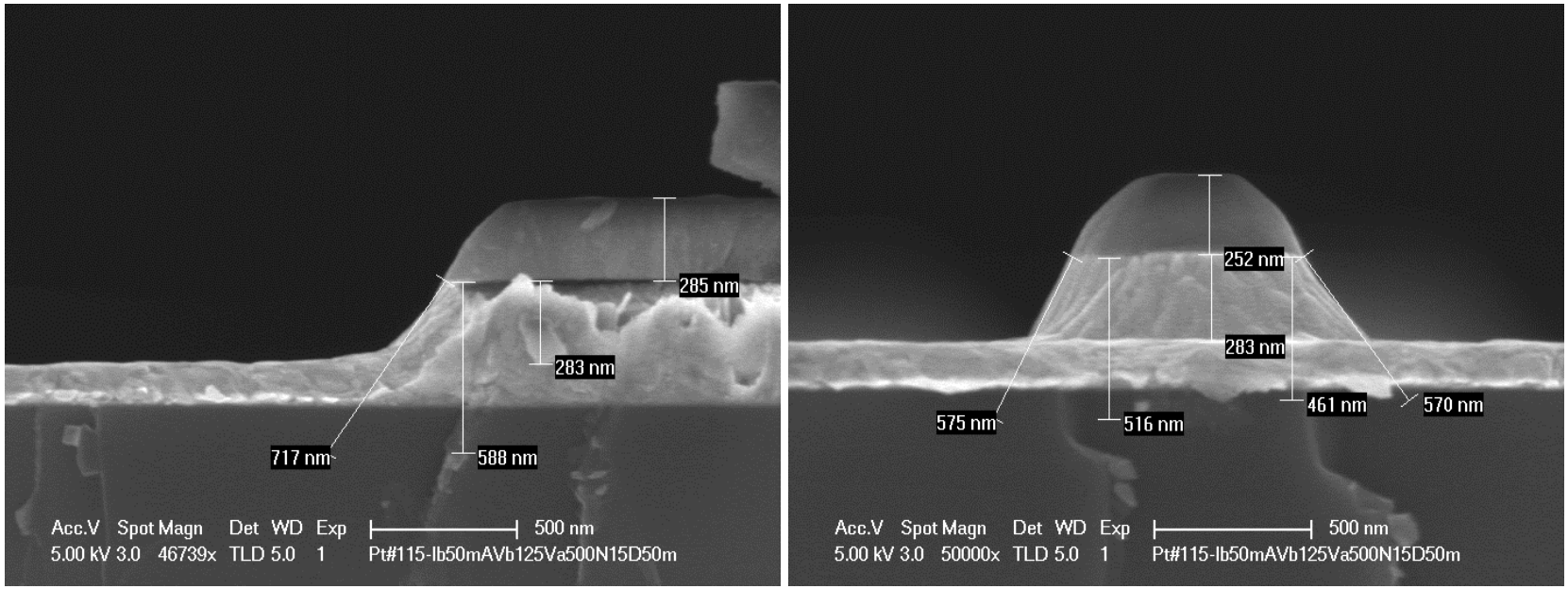


Figure 15 (a) and (b) Cross-section of the milled sample Pt16 with I_n=250mA, P_{rf}=150W, I_b=25mA, V_b=250V, V_a=500V, incident angle=-15^o, and time=50 minutes.

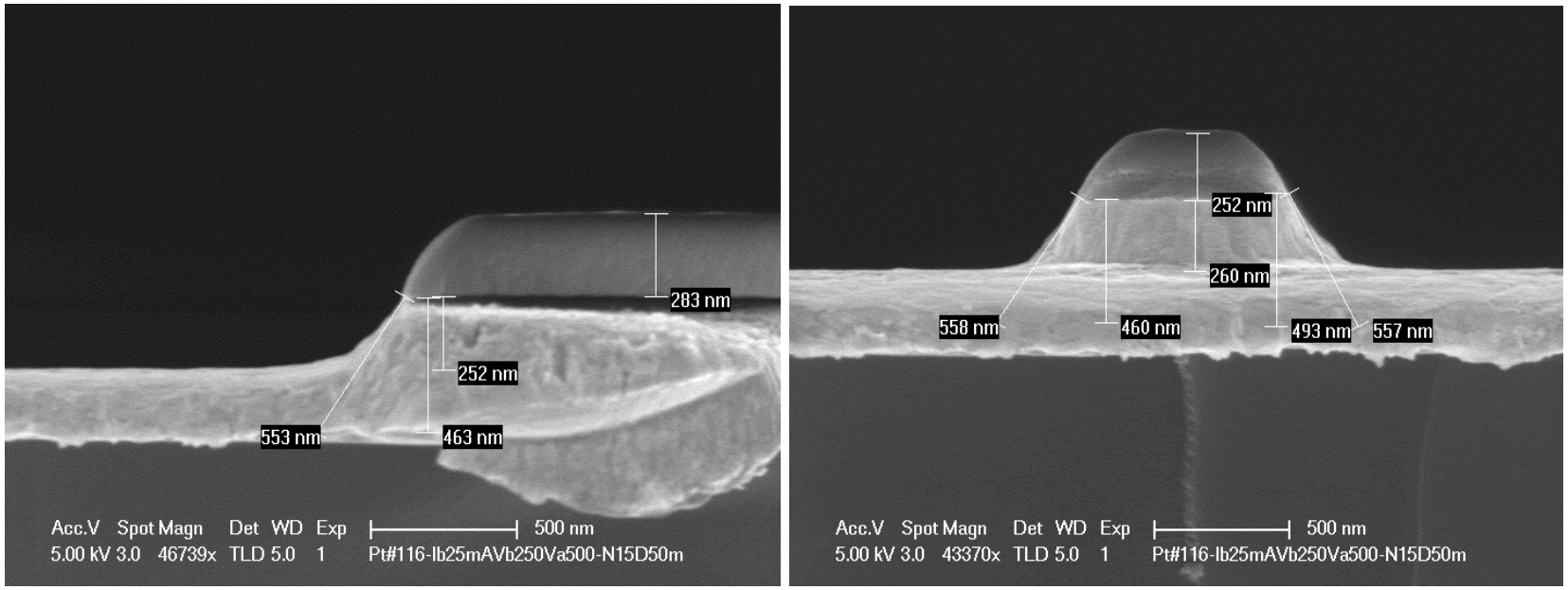


Figure 16 Platinum etch rate and selectivity (Pt/Al_2O_3) as functions of Ar-ion incident angle.

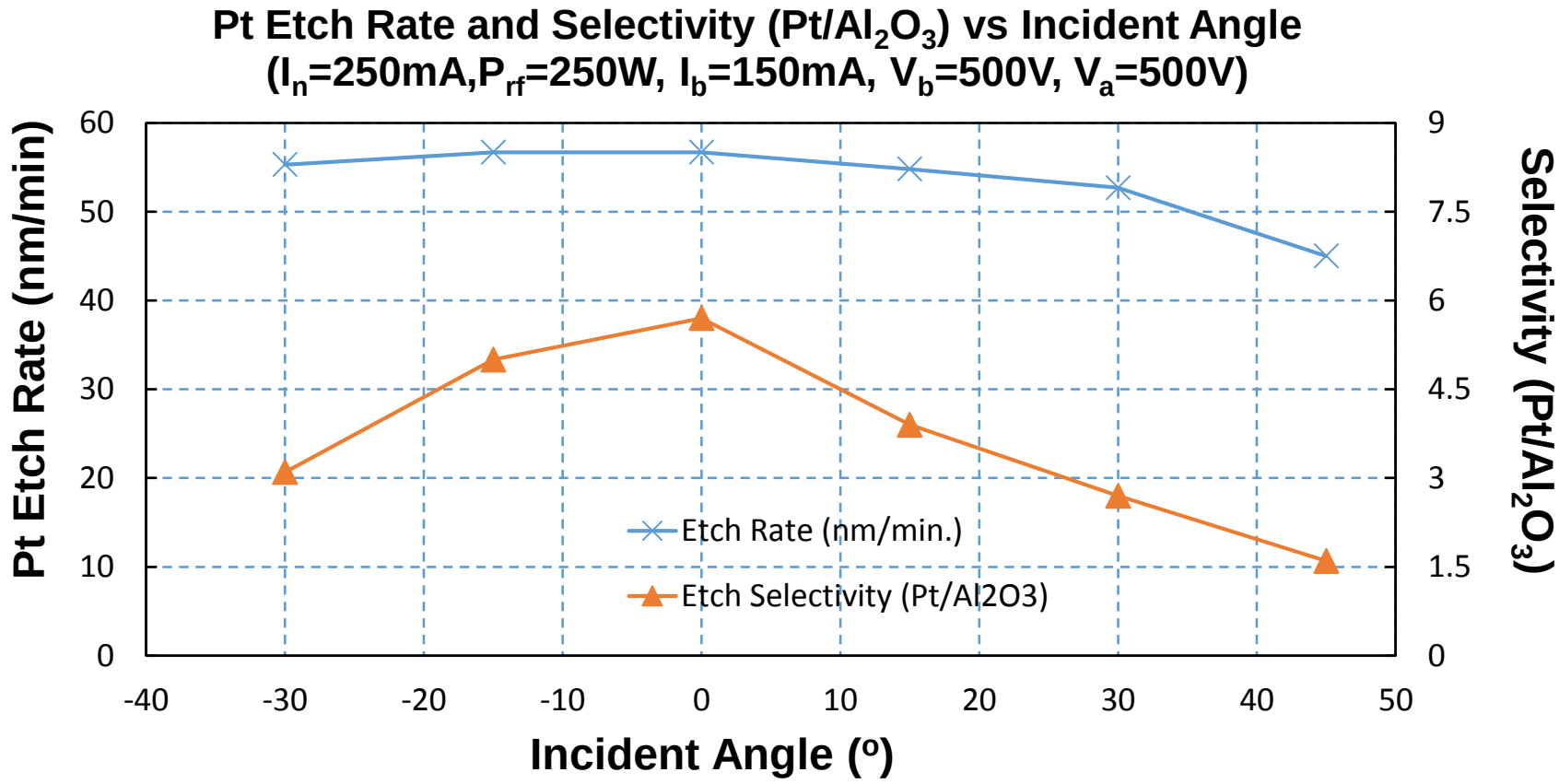


Figure 17 Sidewall angle of etched platinum as a function of Ar-ion incident angle.

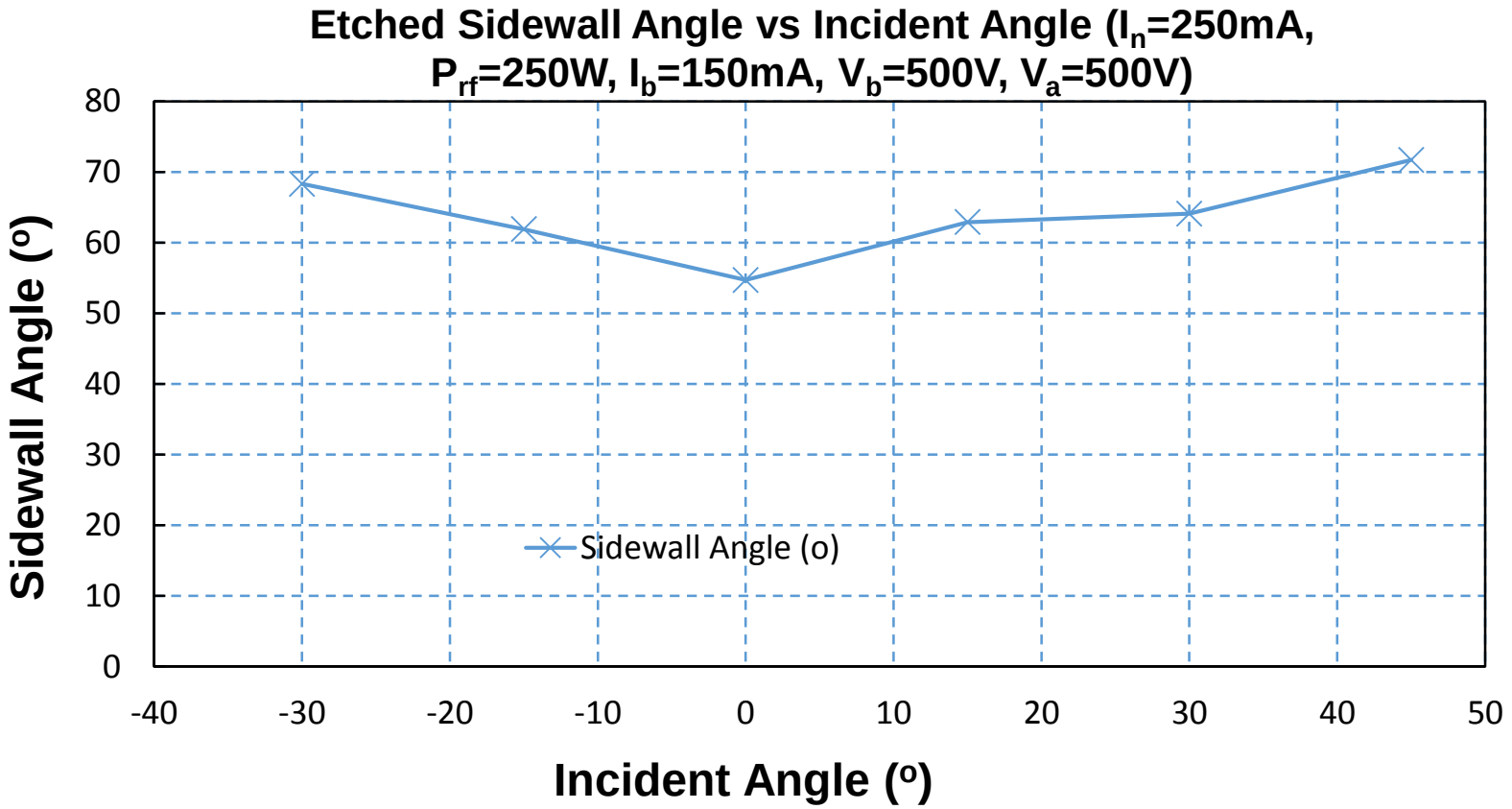


Figure 18 Platinum etch rate and selectivity (Pt/Al_2O_3) as functions of Ar-ion beam current at a beam voltage of 500 V.

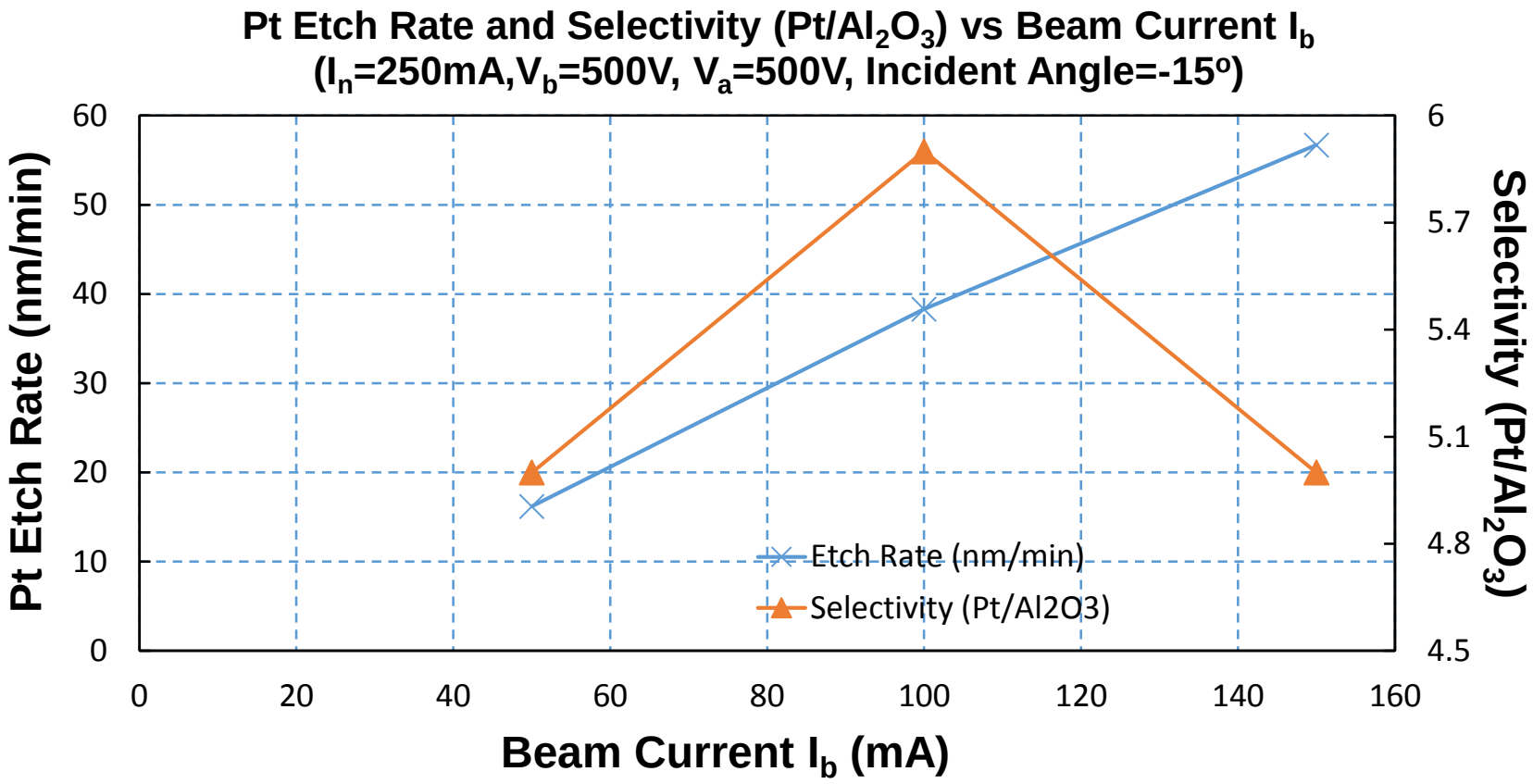


Figure 19 Sidewall angle of etched platinum as a function of Ar-ion beam current at a beam voltage of 500 V.

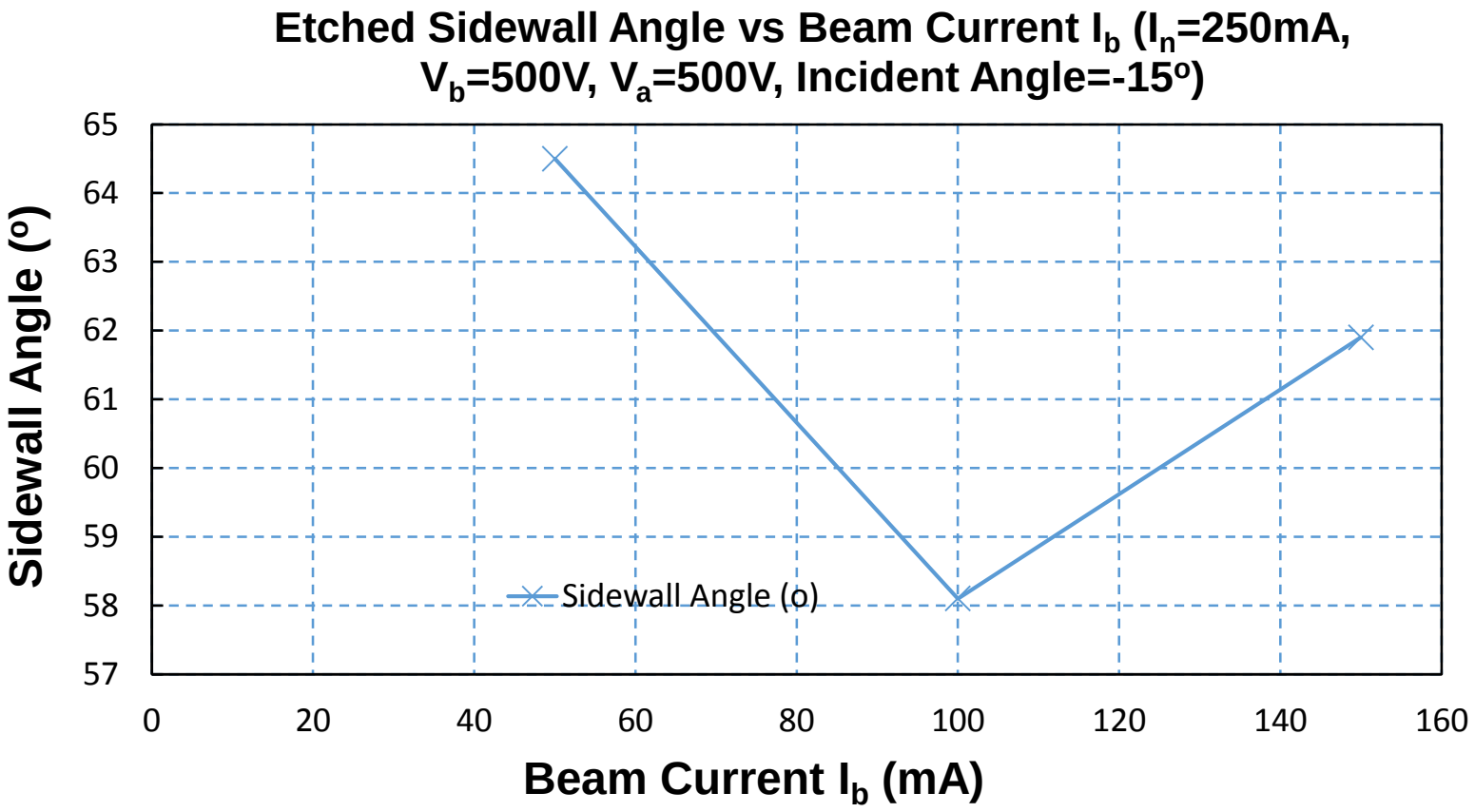


Figure 20 Platinum etch rate and selectivity (Pt/Al_2O_3) as functions of Ar-ion beam current at a beam voltage of 250 V.

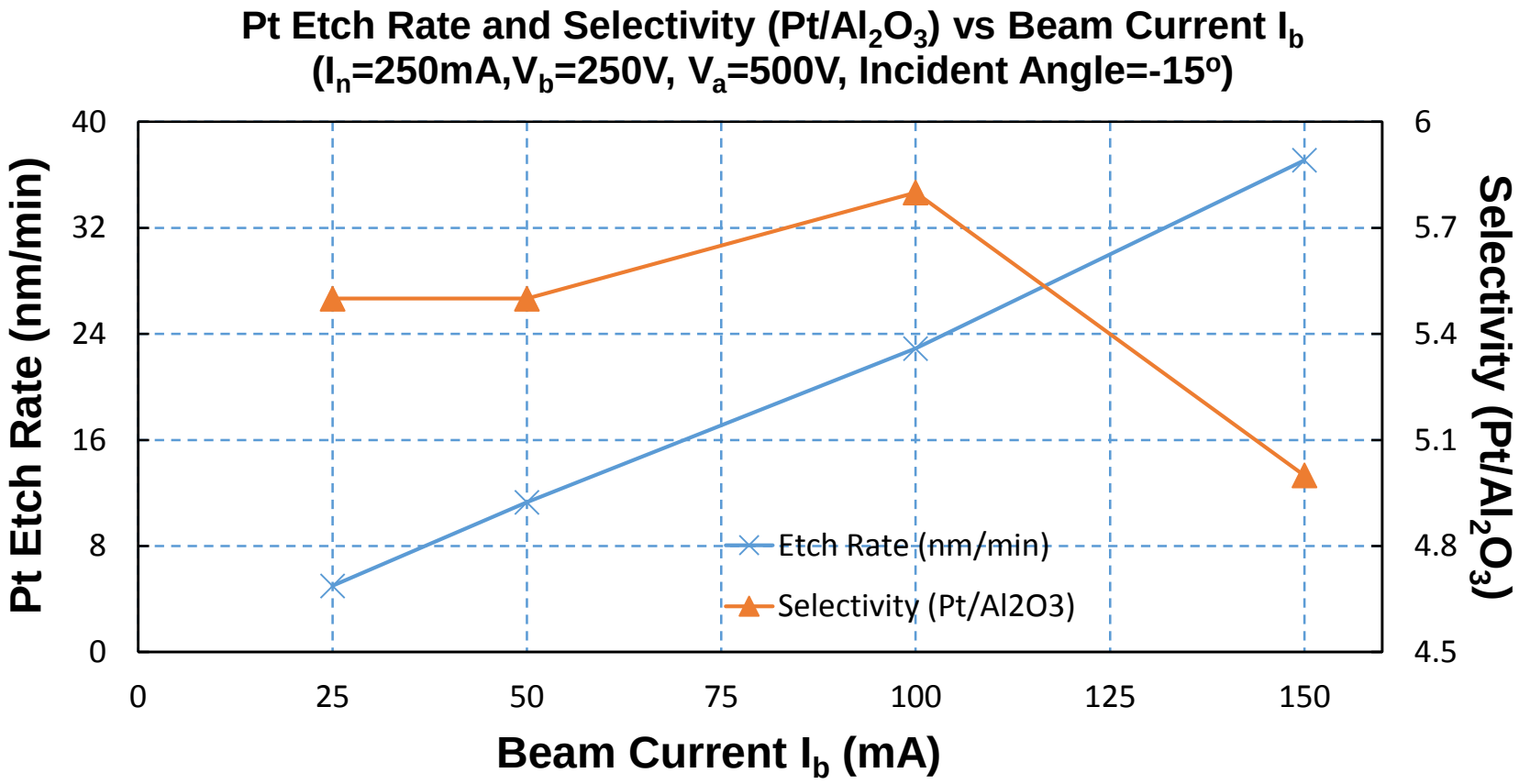


Figure 21 Sidewall angle of etched platinum as a function of Ar-ion beam current at a beam voltage of 250 V.

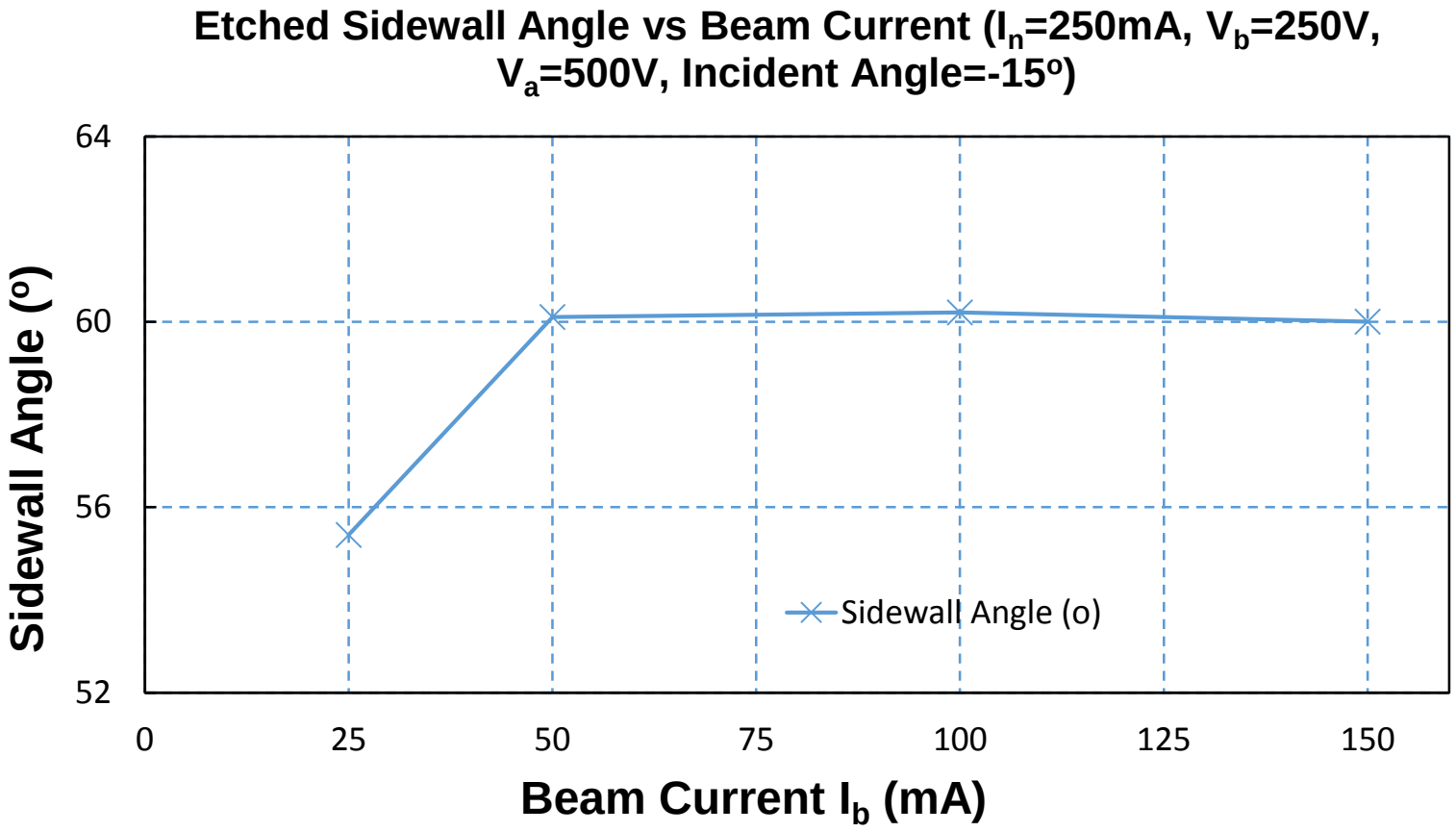


Figure 22 Platinum etch rate and selectivity (Pt/Al_2O_3) as functions of Ar-ion beam voltage at a beam current of 50 mA.

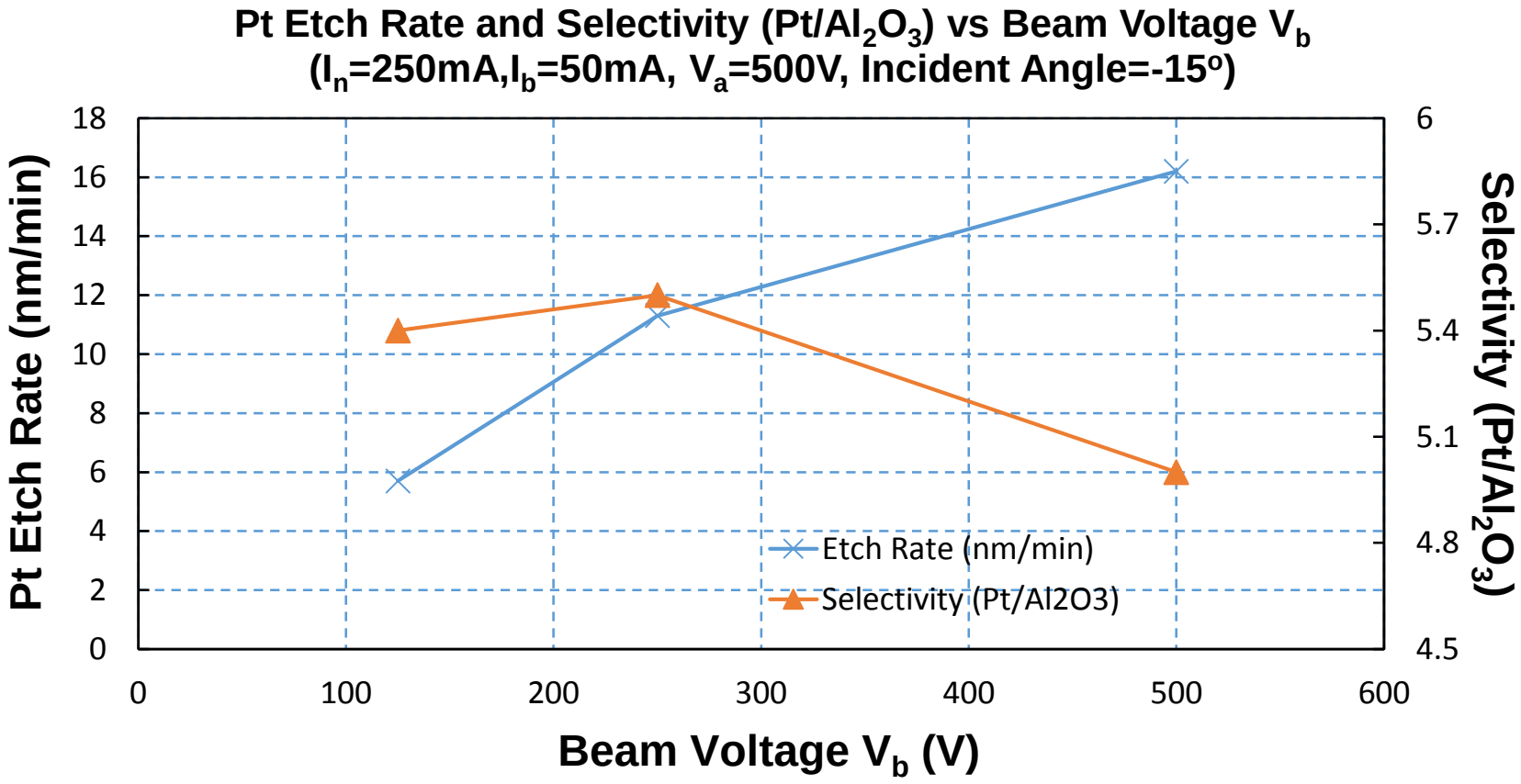


Figure 23 Sidewall angle of etched platinum as a function of Ar-ion beam voltage at a beam current of 50 mA.