

Plasma-etching of AlGaAs DBR Structure using Panasonic ICP Etcher with (Cl₂, N₂) based chemistry

Purpose: To etch AlGaAs and AlAs/GaAs DBR structures with a vertical side-wall profile using Panasonic ICP etcher and Cl₂/N₂ based chemistry.

Material: P-type AlGaAs (~1.9 μm in thickness) and AlAs/GaAs (~4.5 μm in thickness) DBR structures.

Methods:

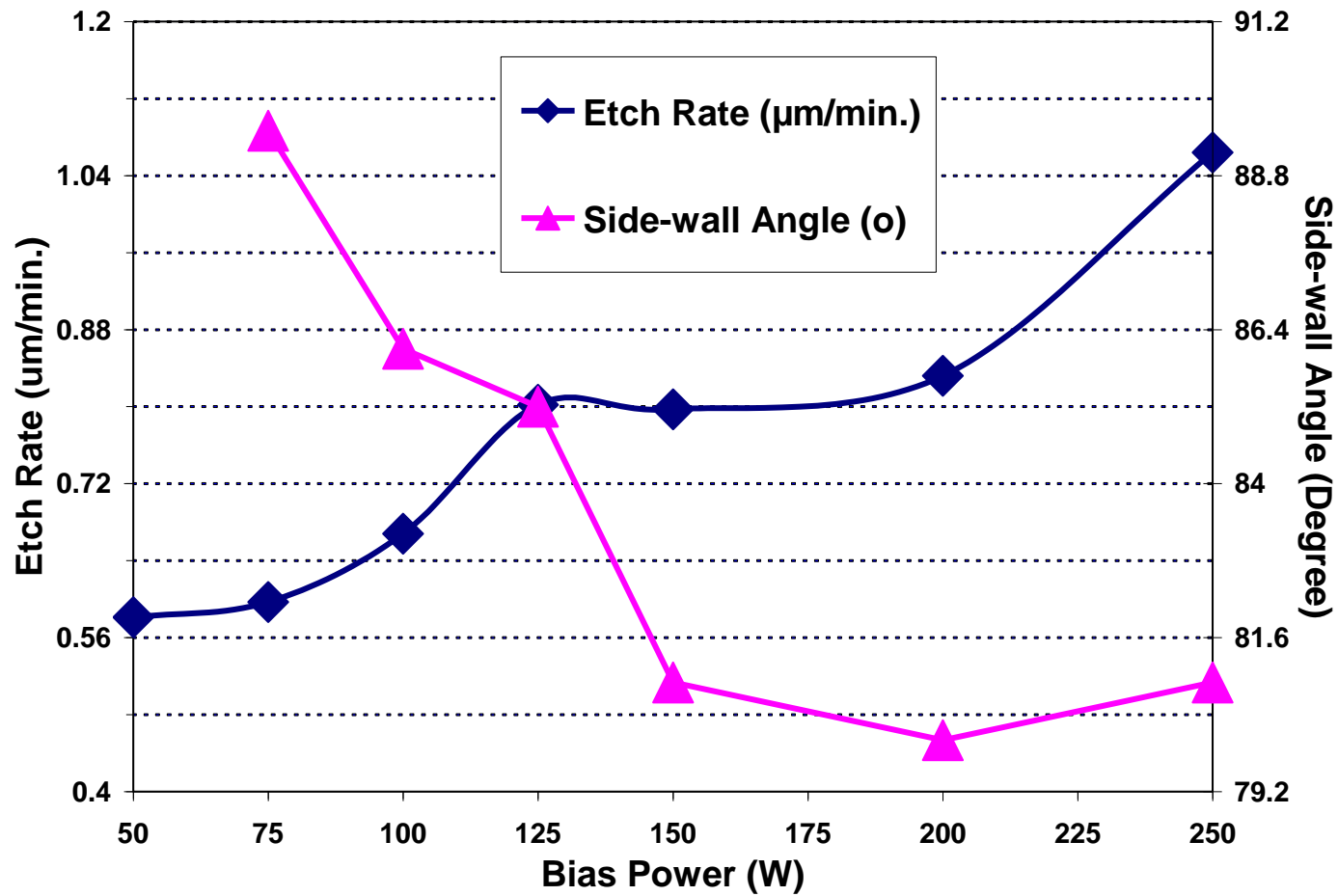
- A 0.5-μm-thick SiO₂ layer was grown on an AlGaAs DBR sample (half of 2" wafer) using Unaxis ICP deposition tool at 100 °C.
- Circles photo-resist pattern (5-μm in diameter) was created using photolithography with a GCA Autostep 200 stepper.
- The circles pattern was transferred into the SiO₂ layer using dry-etching method with Panasonic ICP etcher.
- Remaining photo-resist on the top of circles was stripped using PRX127 photo-resist stripper at 80 °C.
- Etches were performed on sample pieces with the different etch conditions using Panasonic ICP etcher with Cl₂/N₂ chemistry at room-temperature.
- Etch profiles were examined by taking SEM pictures with sample mounted onto a 45° wedge holder.
- The depth of etched sample was measured using a Dektak 6M step profilometer.

Results and Discussions:

Table 1:

Etching of AlGaAs DBR Structure using Panasonic ICP Etcher (E640) at Room-Temperature							
Sample #	Pressure (Pa)	Bias Power (W)	ICP Power (W)	Gas Flowing Rate (sccm)		Etch Rate ($\mu\text{m}/\text{min.}$)	Side-wall Angle ($^\circ$)
				Cl ₂	N ₂		
Grat#1	1	75	900	15	45	0.386	79.3
Grat#2	1	150	900	30	30	0.965	80
Grat#3	1	150	900	15	45	0.601	80.8
Grat#4	0.2	200	900	10	20	0.385	80.4
Grat#5	0.2	200	900	5	25	0.23	77.2
Grat#6	0.2	200	900	20	10	0.832	80
Grat#8	0.2	150	900	20	10	0.797	82.7
Grat#9	0.2	250	900	20	10	1.064	80.9
Grat#10	0.2	100	900	20	10	0.668	86.1
Grat#11	0.2	125	900	20	10	0.802	85.2
Grat#12	0.2	75	900	20	10	0.597	89.5
Grat#13	0.2	50	900	20	10	0.581	n/a

Figure 1 Etch rate and etched side-wall angle of AlGaAs DBR samples as functions of bias power using Panasonic ICP etcher with pressure=0.2 Pa, ICP power=900 W, and Cl₂/N₂ flowing rate=20/10 sccm.



One can see from Fig. 1, generally speaking, the etch rate increases, while the side-wall angle decreases, with the increase of bias power. The side-wall angle reaches almost 90° with the bias power of 75 W. Further decreasing the bias power to 50 W, the side-wall gets undercut, as shown in Fig. 13 below.

Figure 2 Etch profile of AlGaAs DBR structure (grat#1) using Panasonic ICP etcher with Cl_2/N_2 flow rate=15/45 sccm, pressure=1 Pa (7.5 mT), bias/ICP power=75/900 W. The etch rate and side-wall angle are $0.386 \mu\text{m}/\text{min}$. and 79.3° , respectively.

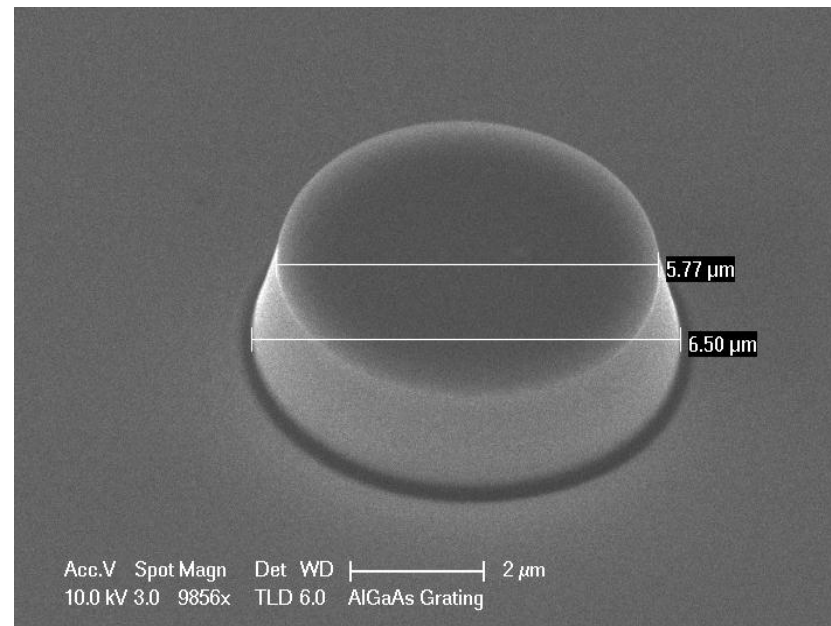


Figure 3 Etch profiles of (a) AlGaAs (grat#2) and (b) AlAs/GaAs (RT#C) DBR structures using Panasonic ICP etcher with Cl_2/N_2 flow rate=30/30 sccm, pressure=1 Pa (7.5 mT), bias/ICP power=150/900 W. The etch rate and side-wall angle are 0.965 $\mu\text{m}/\text{min}$. and 80.0°, respectively.

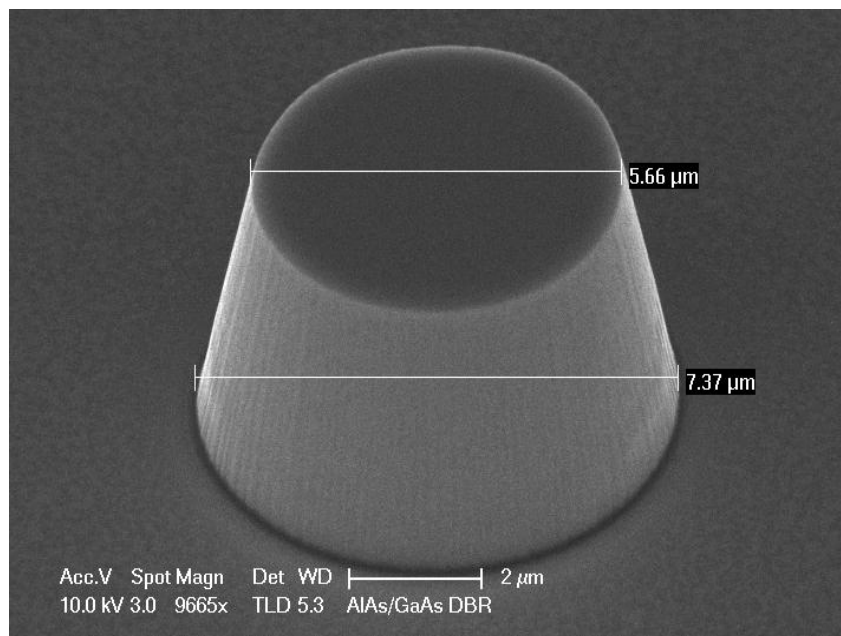
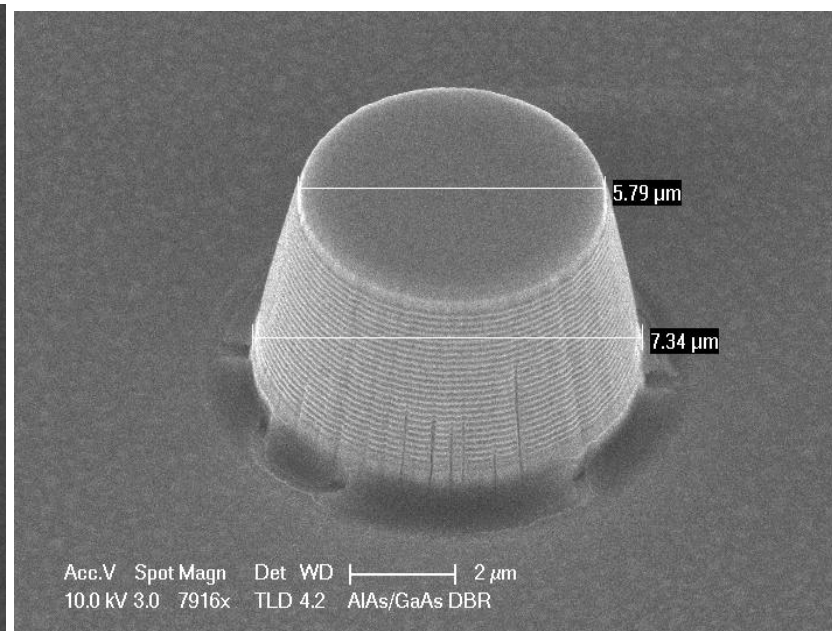
**(a)****(b)**

Figure 4 Etch profile of AlGaAs DBR structure (grat#3) using Panasonic ICP etcher with Cl_2/N_2 flow rate=15/45 sccm, pressure=1 Pa (7.5 mT), bias/ICP power=150/900 W. The etch rate and side-wall angle are $0.601 \mu\text{m}/\text{min}$ and 80.8° , respectively.

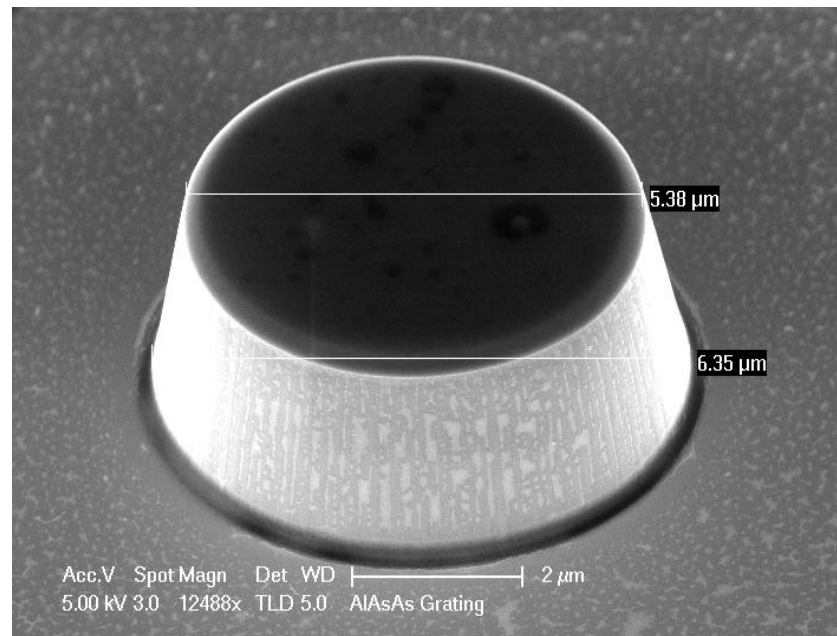


Figure 5 Etch profile of AlGaAs DBR structure (grat#4) using Panasonic ICP etcher with Cl_2/N_2 flow rate=10/20 sccm, pressure=0.2 Pa (1.5 mT), bias/ICP power=200/900 W. The etch rate and side-wall angle are $0.385 \mu\text{m}/\text{min}$. and 80.4° , respectively.

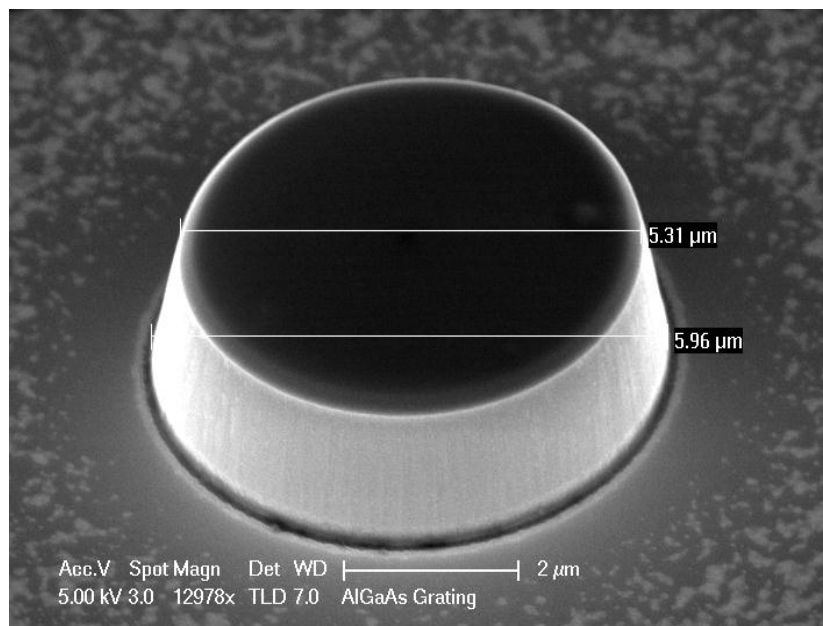


Figure 6 Etch profile of AlGaAs DBR structure (grat#5) using Panasonic ICP etcher with Cl_2/N_2 flow rate=5/25 sccm, pressure=0.2 Pa (1.5 mT), bias/ICP power=200/900 W. The etch rate and side-wall angle are $0.23 \mu\text{m}/\text{min}$. and 77.2° , respectively.

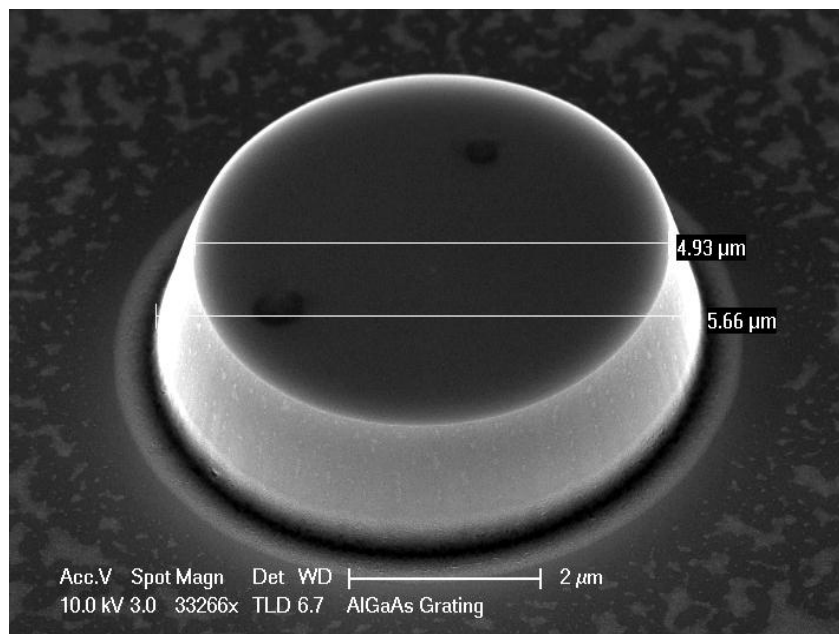


Figure 7 Etch profile of AlGaAs DBR structure (grat#6) using Panasonic ICP etcher with Cl_2/N_2 flow rate=20/10 sccm, pressure=0.2 Pa (1.5 mT), bias/ICP power=200/900 W. The etch rate and side-wall angle are 0.832 $\mu\text{m}/\text{min}$. and 80.0°, respectively.

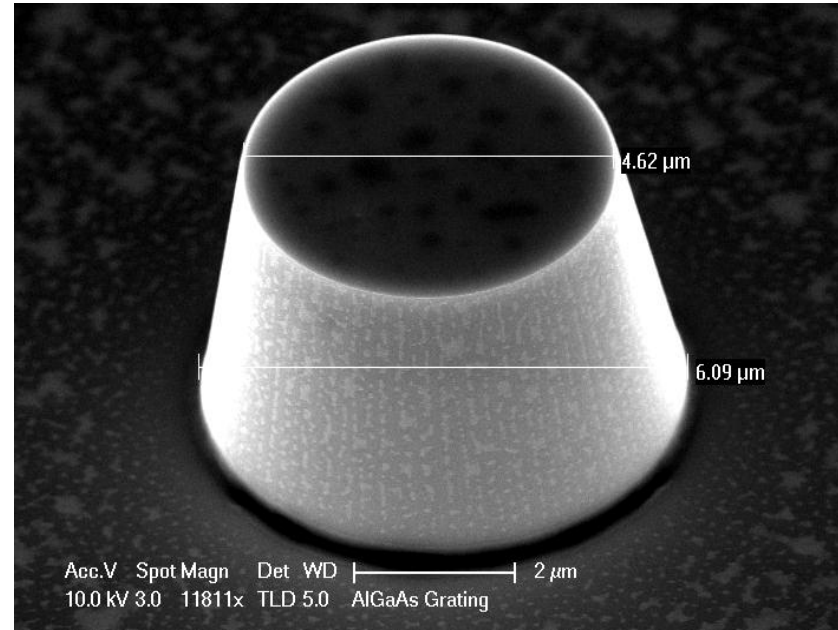


Figure 8 Etch profile of AlGaAs DBR structure (grat#8) using Panasonic ICP etcher with Cl_2/N_2 flow rate=20/10 sccm, pressure=0.2 Pa (1.5 mT), bias/ICP power=150/900 W. The etch rate and side-wall angle are 0.797 $\mu\text{m}/\text{min}$. and 82.7°, respectively.

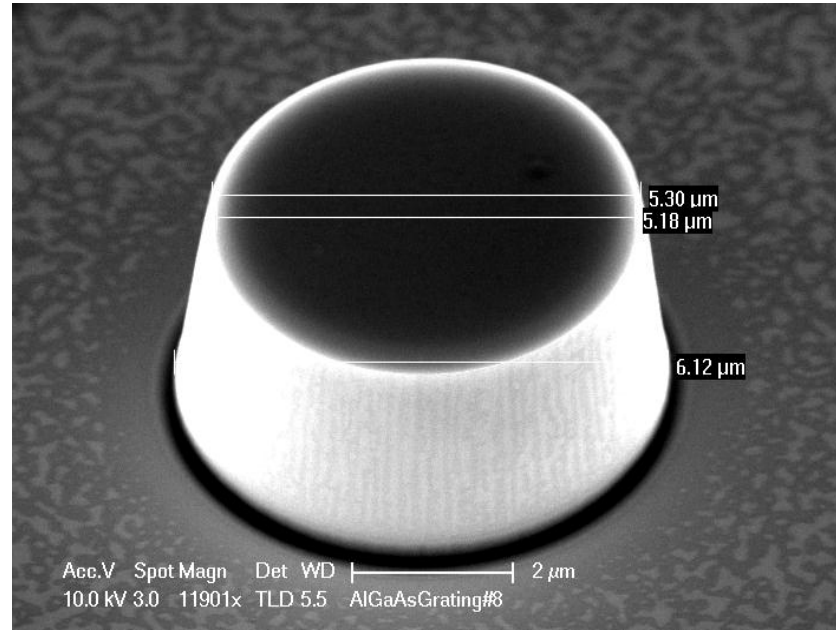


Figure 9 Etch profile of AlGaAs DBR structure (grat#9) using Panasonic ICP etcher with Cl_2/N_2 flow rate=20/10 sccm, pressure=0.2 Pa (1.5 mT), bias/ICP power=250/900 W. The etch rate and side-wall angle are 1.064 $\mu\text{m}/\text{min}$. and 80.9°, respectively.

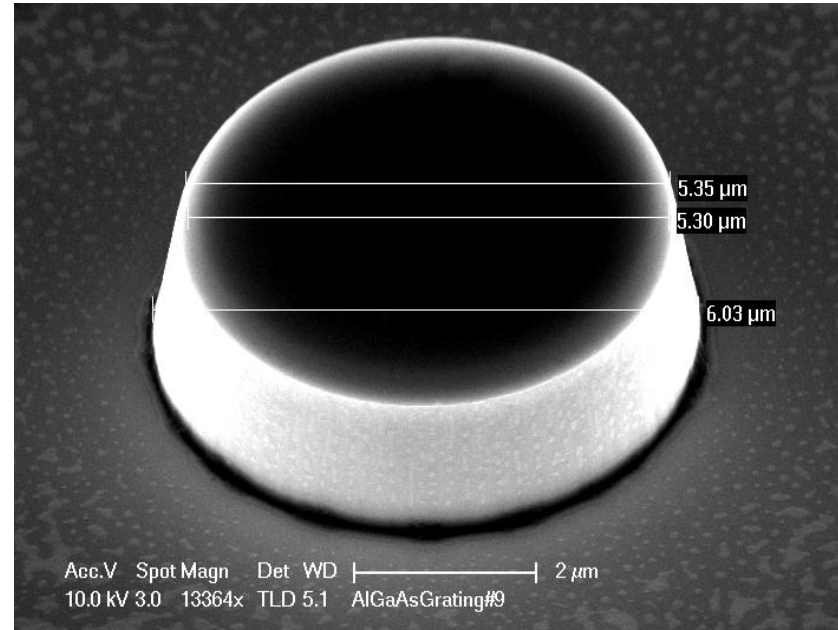


Figure 10 Etch profile of AlGaAs DBR structure (grat#10) using Panasonic ICP etcher with Cl_2/N_2 flow rate=20/10 sccm, pressure=0.2 Pa (1.5 mT), bias/ICP power=100/900 W. The etch rate and side-wall angle are $0.668 \mu\text{m}/\text{min}$. and 86.1° , respectively.

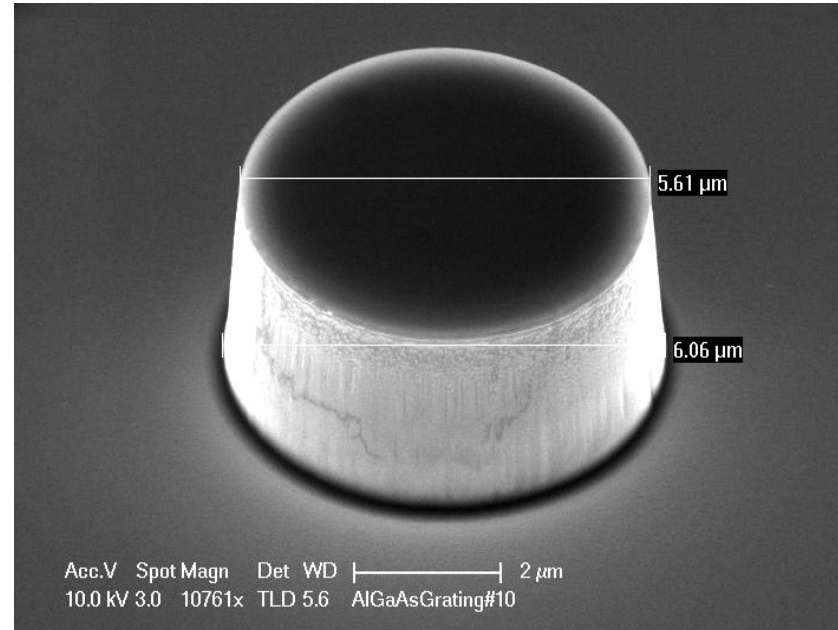


Figure 11 Etch profile of AlGaAs DBR structure (grat#11) using Panasonic ICP etcher with Cl_2/N_2 flow rate=20/10 sccm, pressure=0.2 Pa (1.5 mT), bias/ICP power=125/900 W. The etch rate and side-wall angle are $0.802 \mu\text{m}/\text{min}$. and 85.2° , respectively.

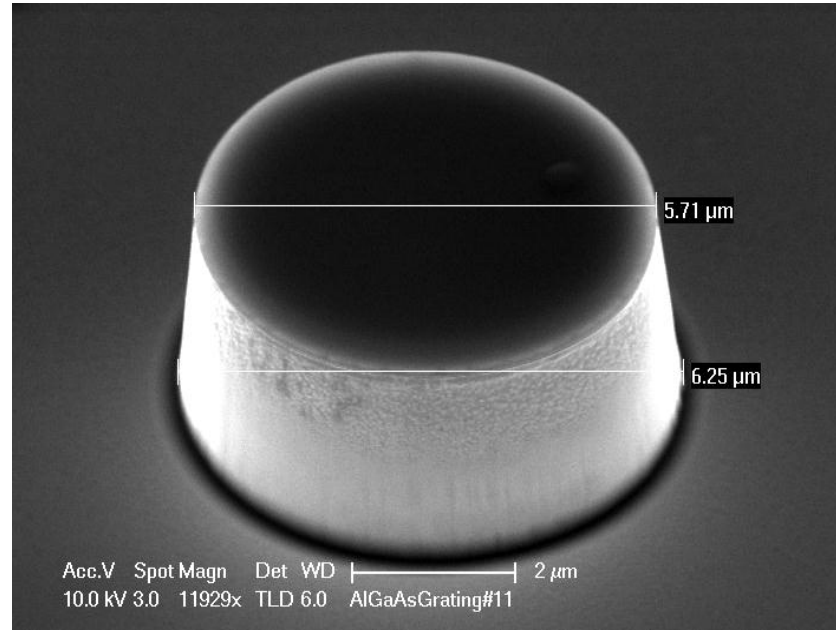


Figure 12 Etch profiles of (a) AlGaAs (grat#12) and (b) AlAs/GaAs (RT#D) DBR structures using Panasonic ICP etcher with Cl_2/N_2 flow rate=20/10 sccm, pressure=0.2 Pa (1.5 mT), bias/ICP power=75/900 W. The etch rate and side-wall angle are 0.597 $\mu\text{m}/\text{min}$. and 89.5°, respectively.

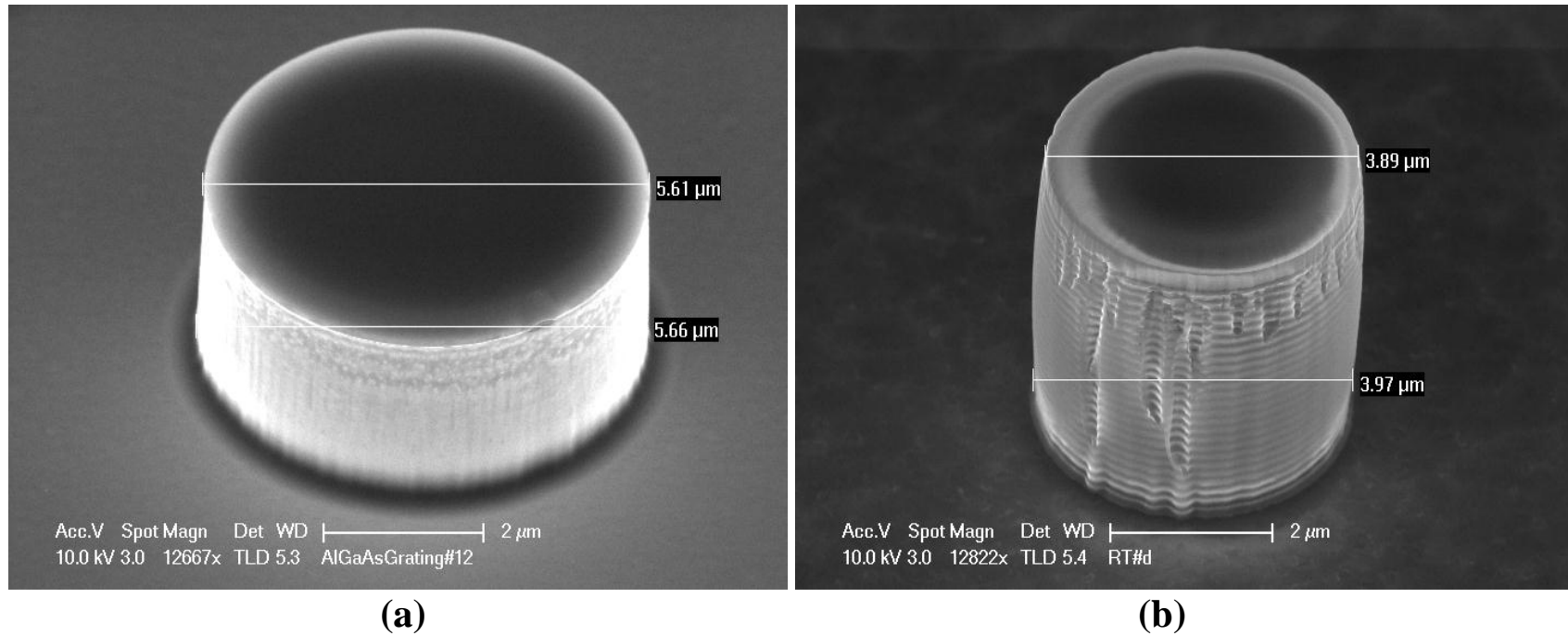


Figure 13 Etch profiles of AlGaAs DBR structure (grat#13) using Panasonic ICP etcher with Cl_2/N_2 flow rate=20/10 sccm, pressure=0.2 Pa (1.5 mT), bias/ICP power=50/900 W. The etch rate is $0.581 \mu\text{m}/\text{min}$. Note that the etched side-wall gets undercut.

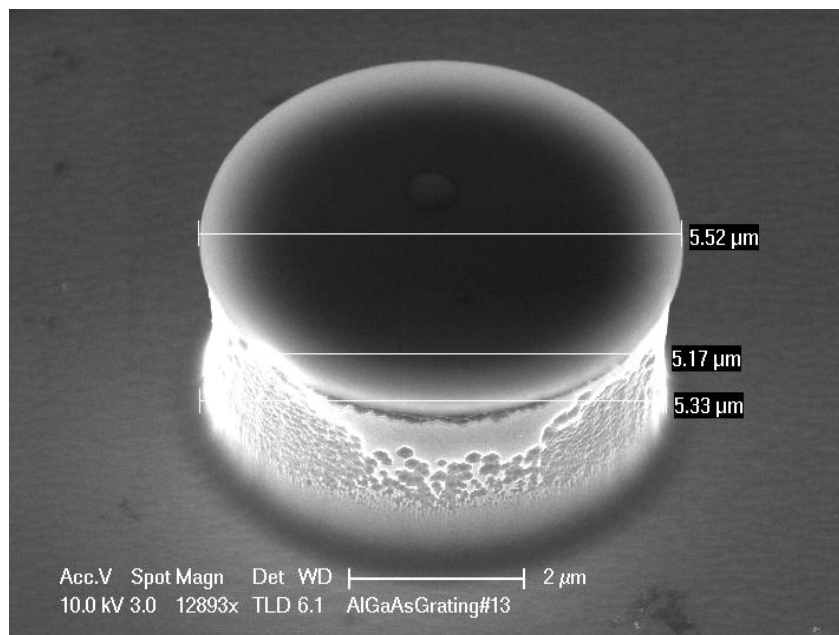
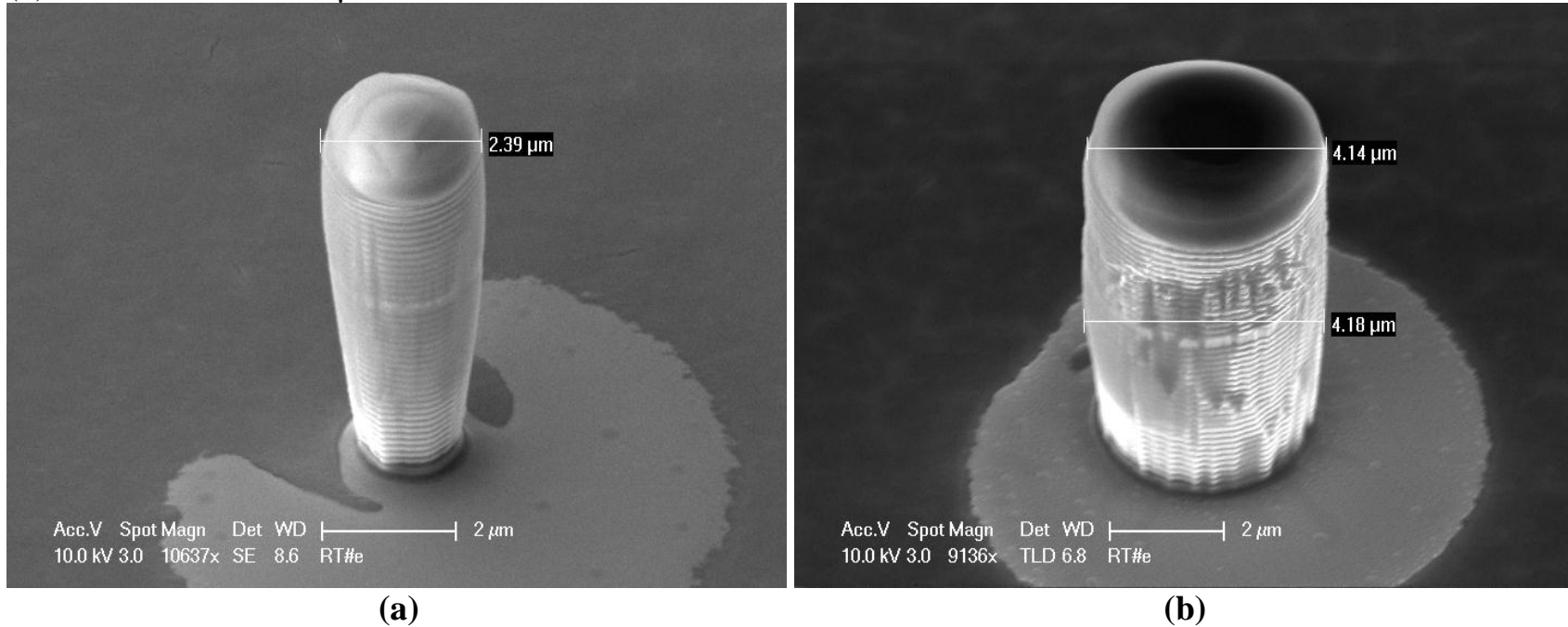


Figure 14 Etch profiles of a real VCSELs structure (RT#E: $\sim 6.3 \mu\text{m}$ in a total thickness) with a InGaAs quantum dots active region sandwiched by top and bottom AlAs/GaAs DBRs using Panasonic ICP etcher with Cl_2/N_2 flow rate=20/10 sccm, pressure=0.2 Pa (1.5 mT), bias/ICP power=75/900 W. (a) a circle mask of 1.5 μm in diameter; (b) a circle mask of 3.0 μm in diameter.



Conclusions: The AlGaAs DBR-structure samples were etched using state-of-art Panasonic ICP etcher with the Cl_2/N_2 chemistry. A vertical side-wall etch profile was obtained using the etching parameters of pressure=0.2 Pa (1.5 mT), bias/ICP powers=75/900 W, Cl_2/N_2 flow rate=20/10 sccm (etch rate $\approx 0.6 \mu\text{m}/\text{min}.$).

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