Optimization of SPR-220-3.0-Photoresist Photolithography Process using CGA Stepper (the old one)

Purpose: Optimization of SPR-220-3.0 photoresist photolithography process with the variation of exposure time and focus offset using the CGA Stepper (the old one).

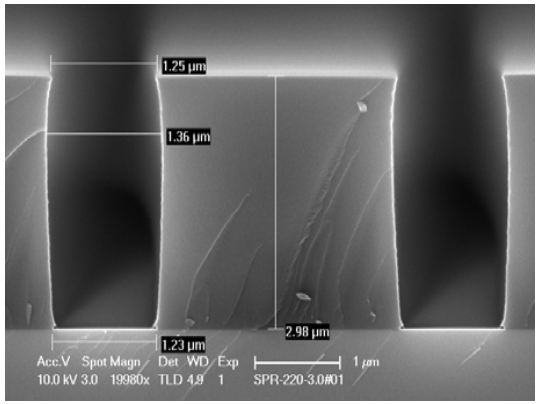
Methods:

- Wafer (4-inch Si wafer) solvent (acetone: 2 minutes; methanol: 1 minute) clean, DI water resin, and N_2 blow dry.
- Wafer dehydration at a hot-plate temperature of 110 ^{0}C for 5 minutes.
- Spin-on HMDS at 4000 rpm for 30s.
- Spin-on SPR-220-3.0 photoresist at 2500 rpm for 30 s.
- Soft bake at a hot-plate temperature of 115 ^{0}C for 90 s.
- Expose the resist using the CGA Stepper (the old one): 6×6 dice with the exposure time ranging from 2 to 3.5 s, step size=0.3 s; the focus offset ranging from -15 to 10, step size=5.
- Post-exposure bake at a hot-plate temperature of 115 ^{0}C for 90 s.
- Develop the exposed resist using MF-701 developer for 60 s.

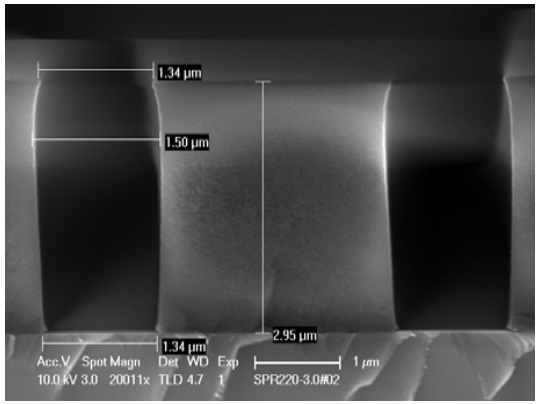
Results:

1) Trenches

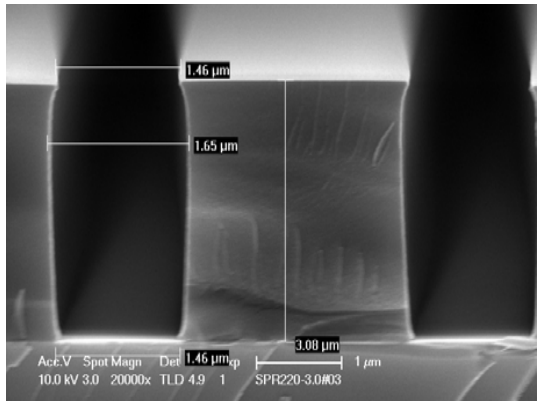
Figure 1. (a) Photoresist profile of nominal trench width of 1.0 μm with (a) exposure time=2.0 s and focus offset= -15; **(b)** exposure time=2.3 s and focus offset= -15; **(c)** exposure time=2.6 s and focus offset= -15; (d) exposure time=2.0 s and focus offset= -10; **(e)** exposure time=2.3 s and focus offset= -10; **(f)** exposure time=2.6 s and focus offset= -10; (g) exposure time=2.0 s and focus offset= -5; **(h)** exposure time=2.3 s and focus offset= -5; **(f)** exposure time=2.6 s and focus offset= -5 (nominal trench width of 0.9 μm).


1.25 µm
1.36 µm
2.98 µm
1.23 µm
Acc.V Spot Magn Det WD Exp 1 µm
10.0 kV 3.0 19980x TLD 4.9 1 SPR-220-3.0#01

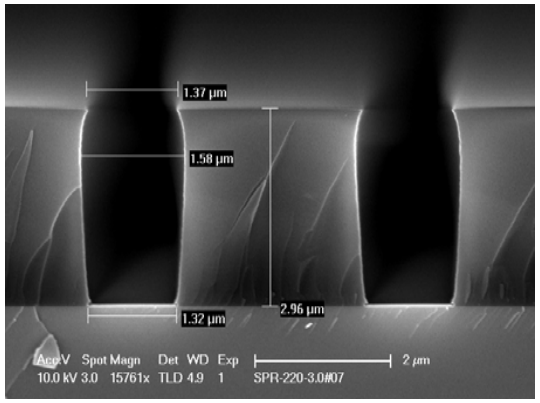
(a)


1.34 µm
1.50 µm
2.95 µm
1.34 µm
Acc.V Spot Magn Det WD Exp 1 µm
10.0 kV 3.0 20011x TLD 4.7 1 SPR220-3.0#02

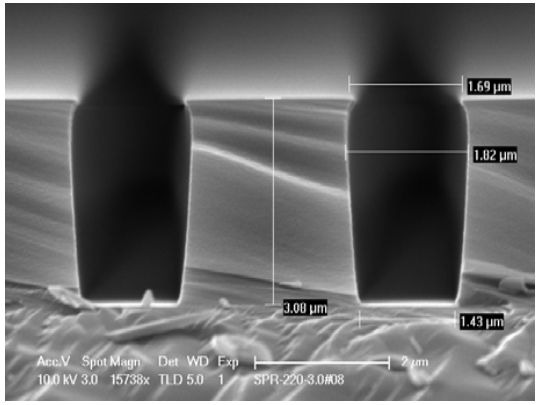
(b)


1.46 µm
1.65 µm
3.08 µm
1.46 µm
Acc.V Spot Magn Det WD Exp 1 µm
10.0 kV 3.0 20000x TLD 4.9 1 SPR220-3.0#03

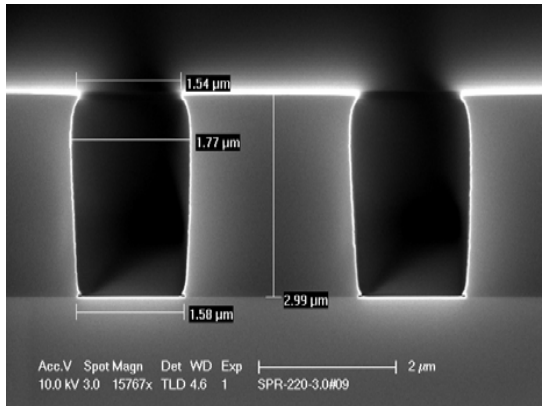
(c)


1.37 µm
1.58 µm
2.96 µm
1.32 µm
Acc.V Spot Magn Det WD Exp 2 µm
10.0 kV 3.0 15761x TLD 4.9 1 SPR-220-3.0#07

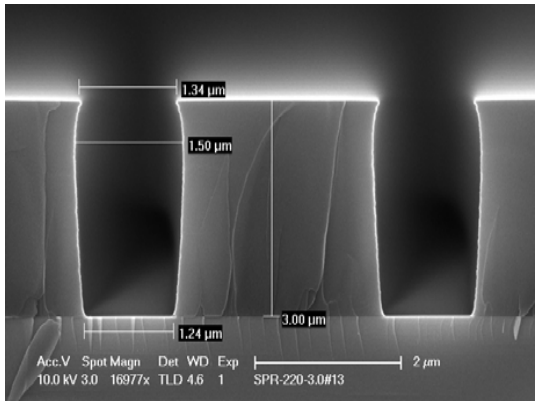
(d)


1.69 µm
1.02 µm
3.08 µm
1.43 µm
Acc.V Spot Magn Det WD Exp 2 µm
10.0 kV 3.0 15738x TLD 5.0 1 SPR-220-3.0#08

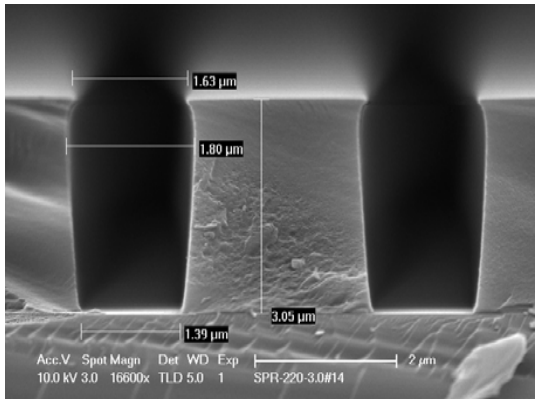
(e)


1.54 µm
1.77 µm
2.99 µm
1.58 µm
Acc.V Spot Magn Det WD Exp 2 µm
10.0 kV 3.0 15767x TLD 4.6 1 SPR-220-3.0#09

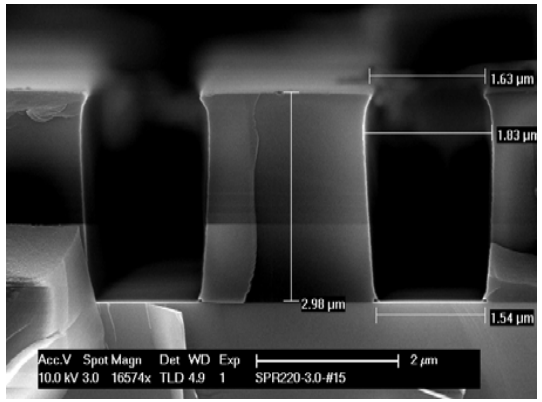
(f)


1.34 µm
1.50 µm
3.00 µm
1.24 µm
Acc.V Spot Magn Det WD Exp
10.0 kV 3.0 16977x TLD 4.6 1
SPR-220-3.0#13
2 µm

(g)


1.63 µm
1.80 µm
3.05 µm
1.39 µm
Acc.V Spot Magn Det WD Exp
10.0 kV 3.0 16600x TLD 5.0 1
SPR-220-3.0#14
2 µm

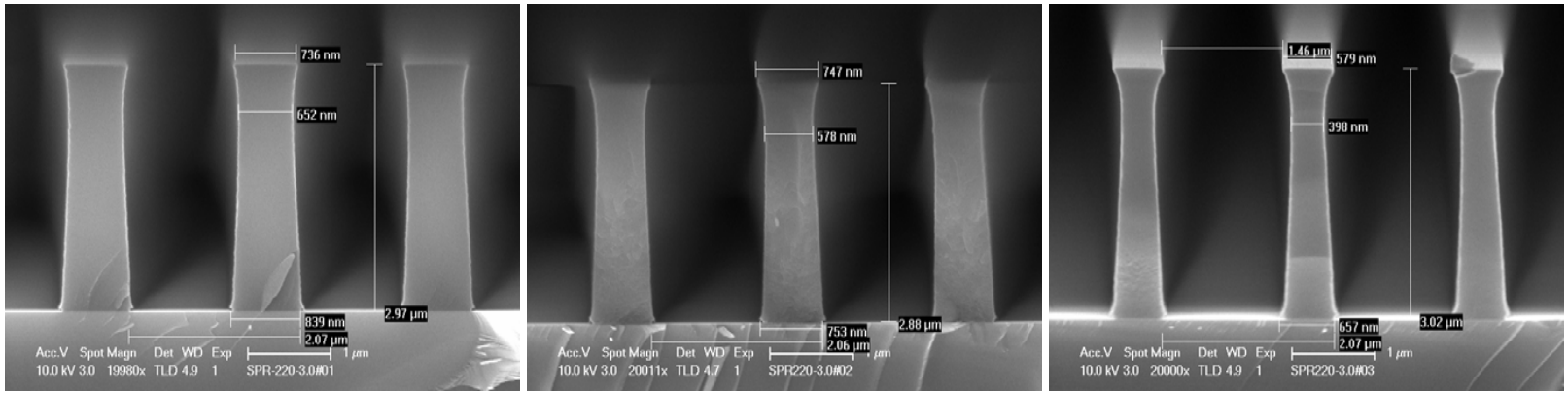
(h)


1.63 µm
1.83 µm
2.98 µm
1.54 µm
Acc.V Spot Magn Det WD Exp
10.0 kV 3.0 16574x TLD 4.9 1
SPR220-3.0-#15
2 µm

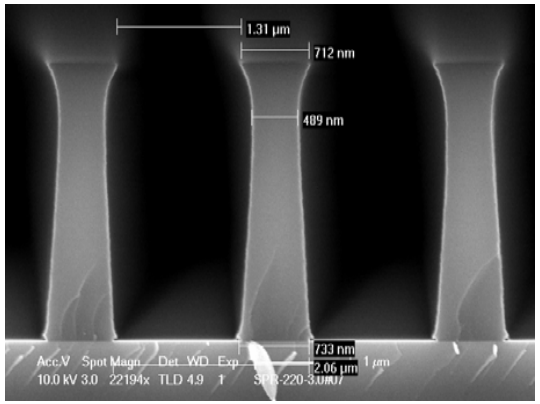
(i)

2) Dense Lines

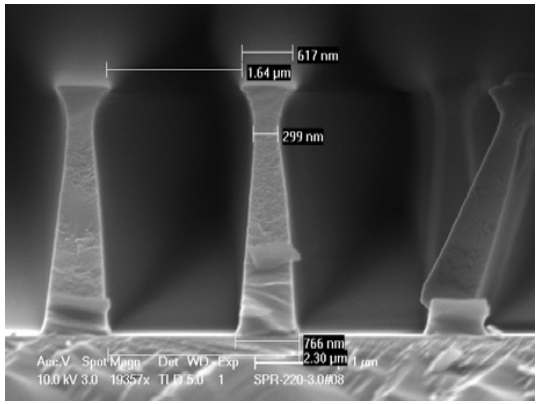
Figure 2. Photoresist profile of dense lines with **(a)** nominal pitch=2.0 µm (nominal 1.0 µm trench and nominal 1.0 µm line widths on the mask), exposure time=2.0 s and focus offset=-15; **(b)** nominal pitch =2.0 µm, exposure time=2.3 s and focus offset=-15; **(c)** nominal pitch=2.0 µm, exposure time=2.6 s and focus offset=-15; **(d)** nominal pitch=2.0 µm, exposure time=2.0 s and focus offset=-10; **(e)** nominal pitch=2.2 µm, exposure time=2.3 s and focus offset=-10; **(f)** nominal pitch=2.2 µm, exposure time=2.6 s and focus offset=-10; **(g)** nominal pitch=2.0 µm, exposure time=2.0 s and focus offset=-5; **(h)** nominal pitch=2.2 µm, exposure time=2.3 s and focus offset=-5; **(i)** nominal pitch=2.8 µm, exposure time=2.6 s and focus offset=-5.



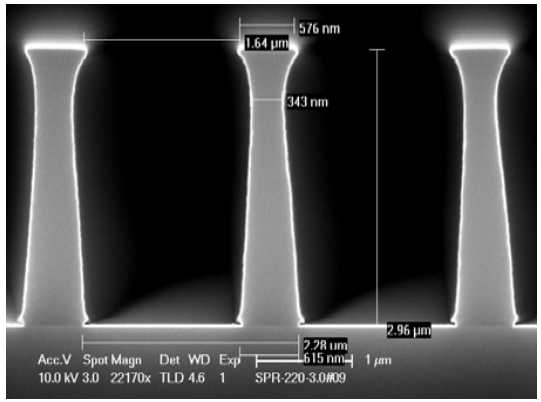
(a) **(b)** **(c)**


1.31 µm
712 nm
489 nm
733 nm
2.06 µm
1 µm
Acc.V Spot Magn Det WD Exp
10.0 kV 3.0 22194x TLD 4.9 1

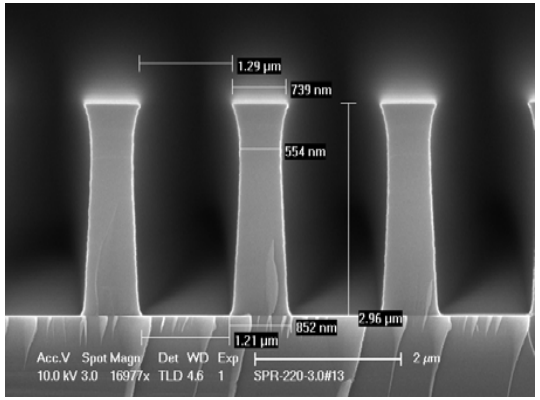
(d)


617 nm
1.64 µm
299 nm
766 nm
2.30 µm
1 µm
Acc.V Spot Magn Det WD Exp
10.0 kV 3.0 19357x TLD 5.0 1
SPR-220-3.0#08

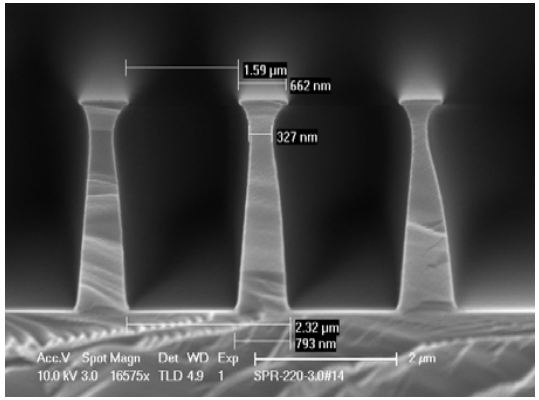
(e)


576 nm
1.64 µm
343 nm
2.96 µm
2.28 µm
615 nm
1 µm
Acc.V Spot Magn Det WD Exp
10.0 kV 3.0 22170x TLD 4.6 1
SPR-220-3.0#09

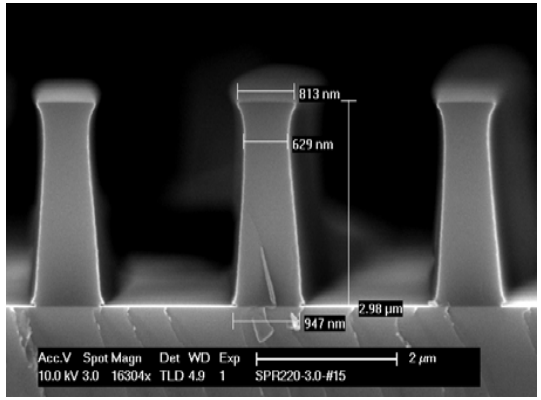
(f)


1.29 µm
739 nm
554 nm
2.96 µm
852 nm
1.21 µm
2 µm
Acc.V Spot Magn Det WD Exp
10.0 kV 3.0 16977x TLD 4.6 1
SPR-220-3.0#13

(g)


1.59 µm
662 nm
327 nm
2.32 µm
793 nm
2 µm
Acc.V Spot Magn Det WD Exp
10.0 kV 3.0 16575x TLD 4.9 1
SPR-220-3.0#14

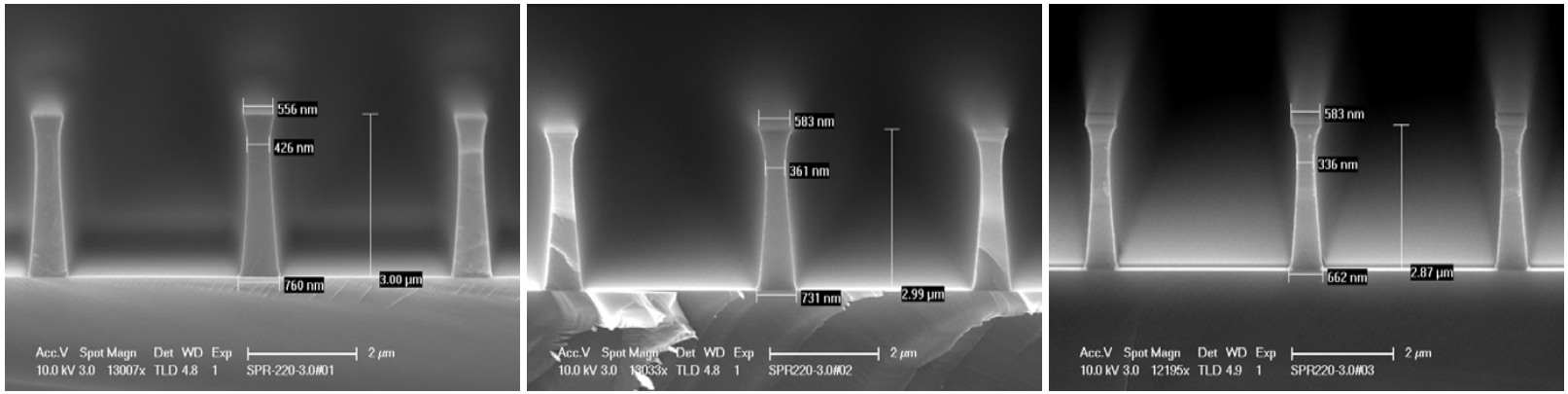
(h)


813 nm
629 nm
2.98 µm
947 nm
2 µm
Acc.V Spot Magn Det WD Exp
10.0 kV 3.0 16304x TLD 4.9 1
SPR220-3.0-#15

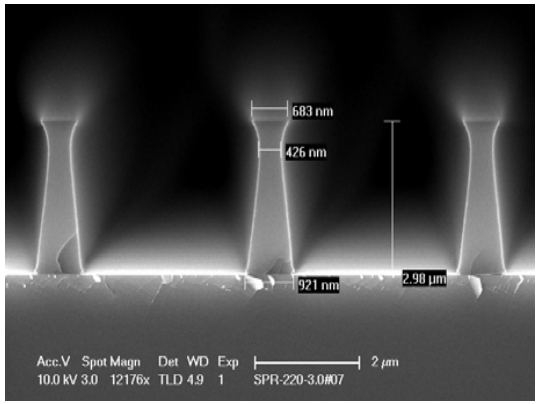
(i)

3) Extended Lines

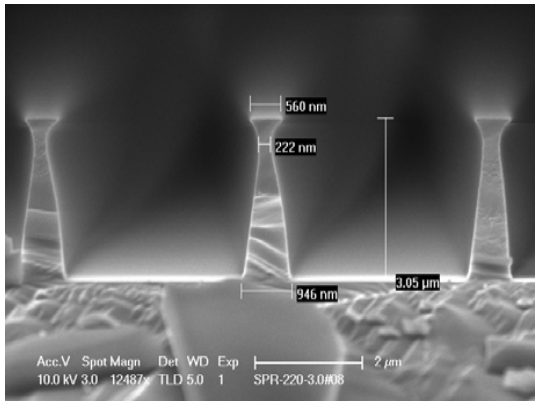
Figure 3. Photoresist profile of extended lines with **(a)** nominal line width=0.80 µm, exposure time=2.0 s and focus offset=-15; **(b)** nominal line width =0.85 µm, exposure time=2.3 s and focus offset=-15; **(c)** nominal line width=0.95 µm, exposure time=2.6 s and focus offset=-15; **(d)** nominal line width=0.95 µm, exposure time=2.0 s and focus offset=-10; **(e)** nominal line width=1.1 µm, exposure time=2.3 s and focus offset=-10; **(f)** nominal line width=1.1 µm, exposure time=2.6 s and focus offset=-10; **(g)** nominal line width=1.0 µm, exposure time=2.0 s and focus offset=-5; (h) nominal line width=1.1 µm, exposure time=2.3 s and focus offset=-5; (i) nominal line width=1.4 µm, exposure time=2.6 s and focus offset=-5.



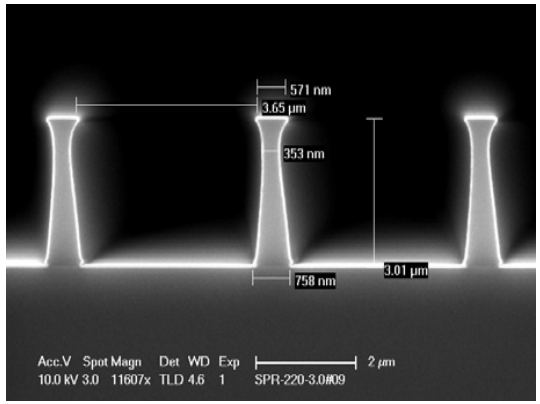
(a) **(b)** **(c)**



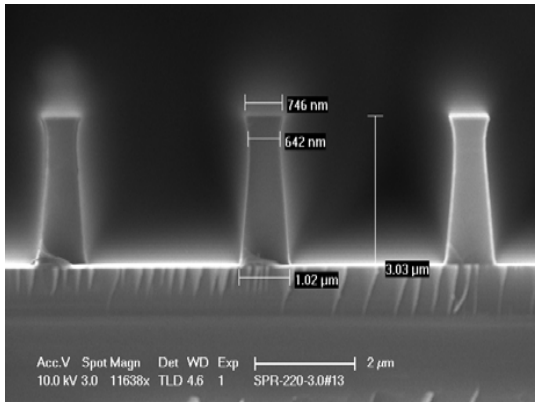
(d)



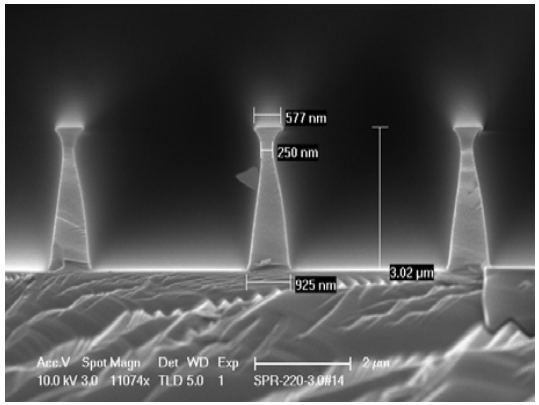
(e)



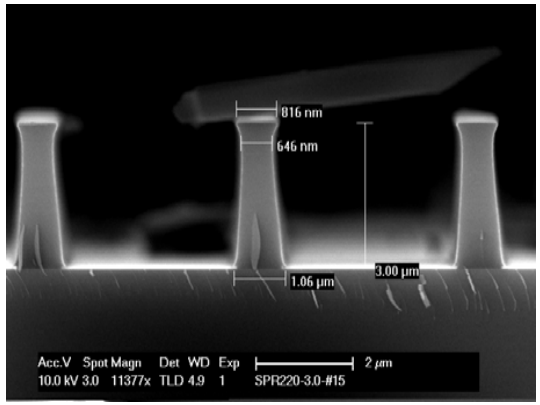
(f)



(g)



(h)



(i)

Conclusions:

As one can see from above profiles, the optimized combination of exposure time and focus offset for the SPR-220-3.0 photoresist is 2.0 s and -15, respectively, when using the old CGA Stepper. The resist thickness is 3 µm when using these spin-on speed and post exposure bake temperature (2500 rpm and 115 C, respectively) I do not show the resist profiles for the positive values of focus offset, 0, 5, 10, because the profiles with those focus offset values are not consistent.