Optimization of Electron Beam Lithography for the Fabrication of Nanostructured Optical Devices

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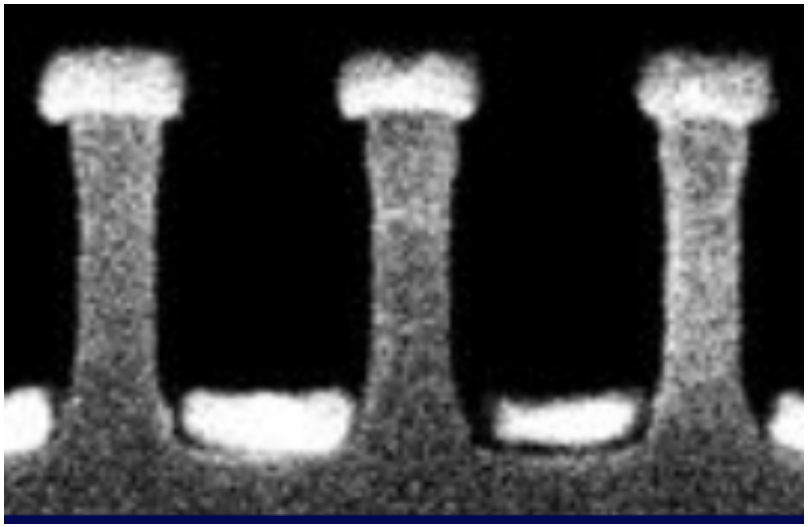
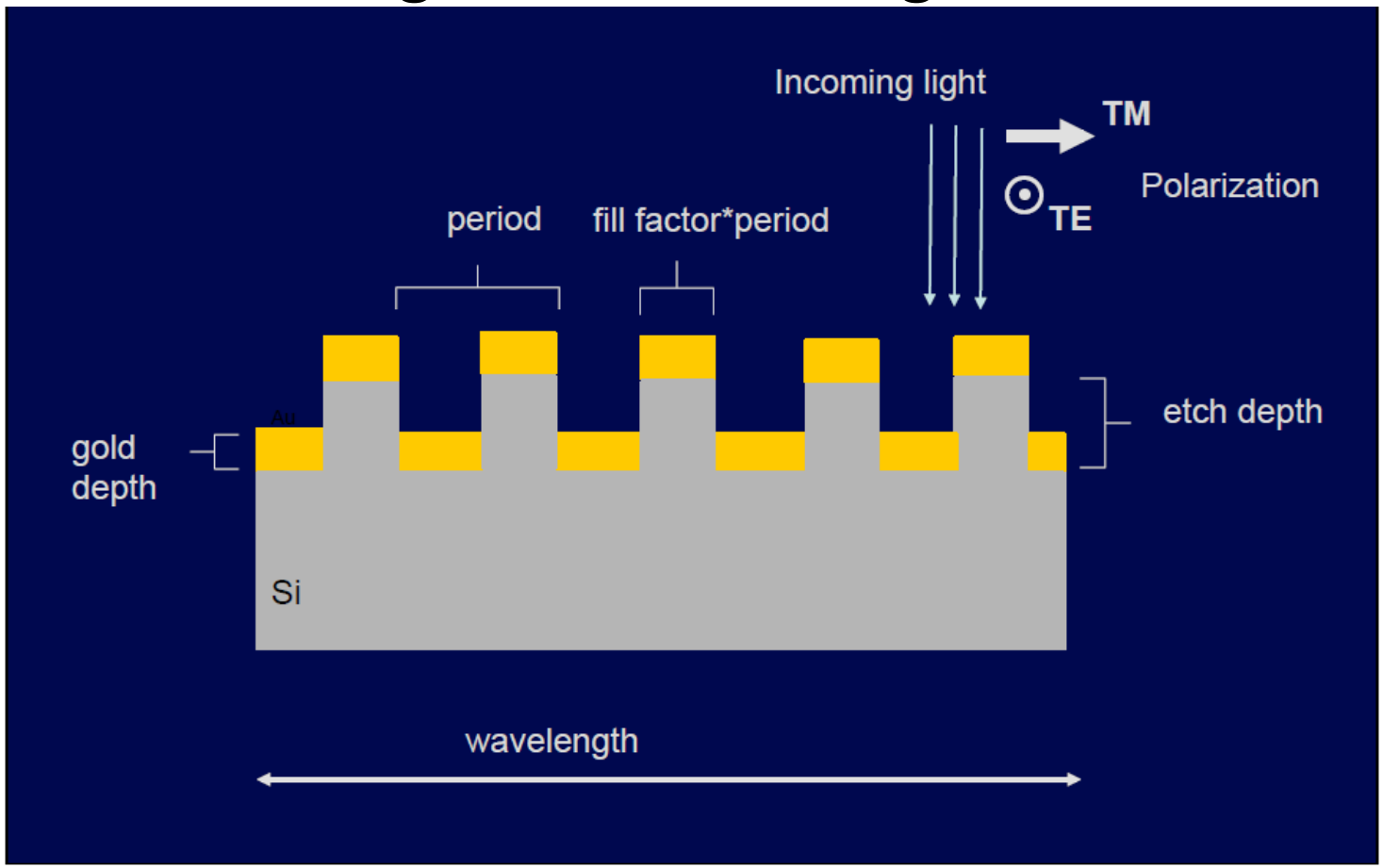


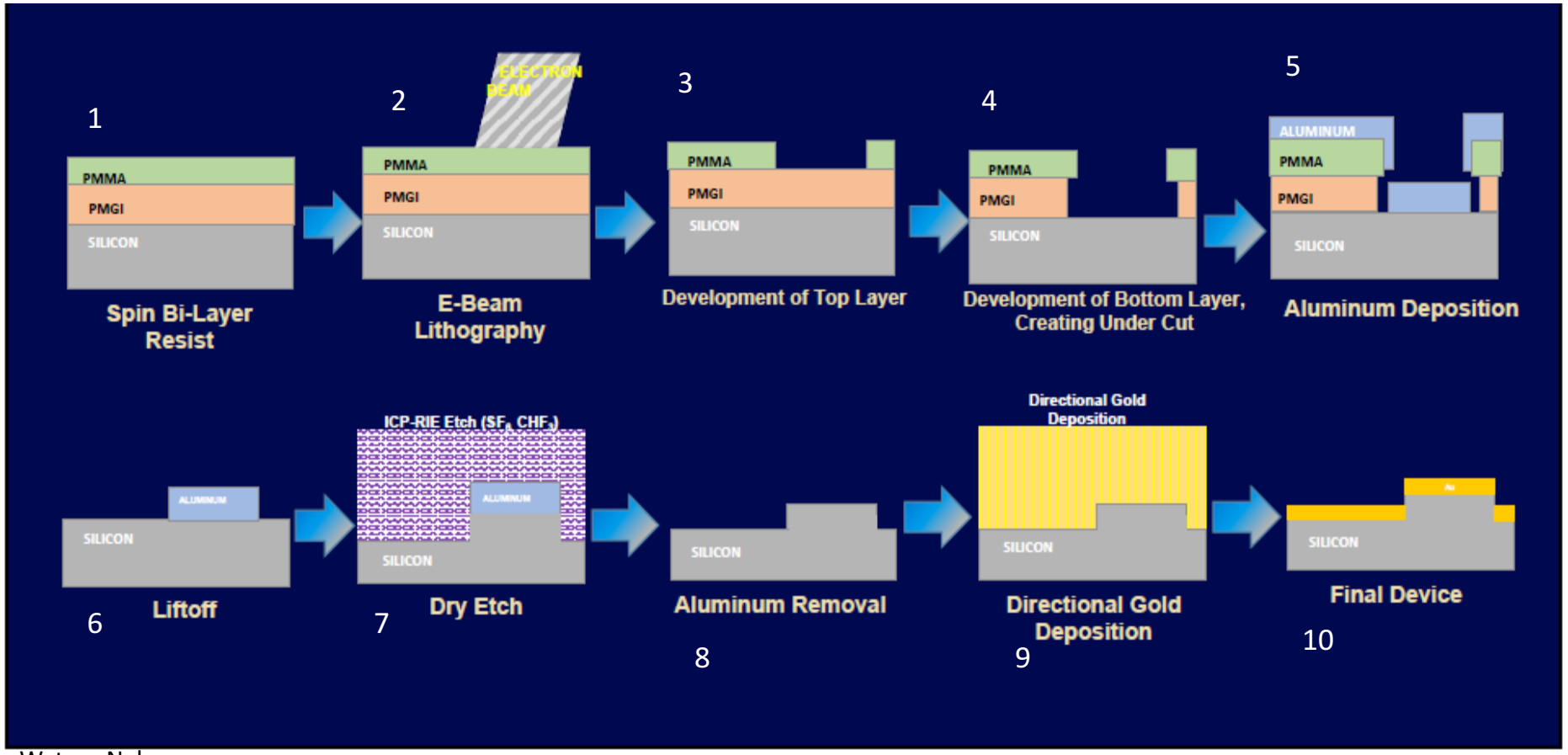
Project Goal

- Optimize the nano-fabrication process in order to reproducibly create functional polarizing devices which select a specific polarization state and wavelength in the IR Range



- Expected Periods: 1µm, 800nm, 600nm, 400nm, 300nm, 200nm
- Ideal Fill Factor: 50%

Fabrication Process



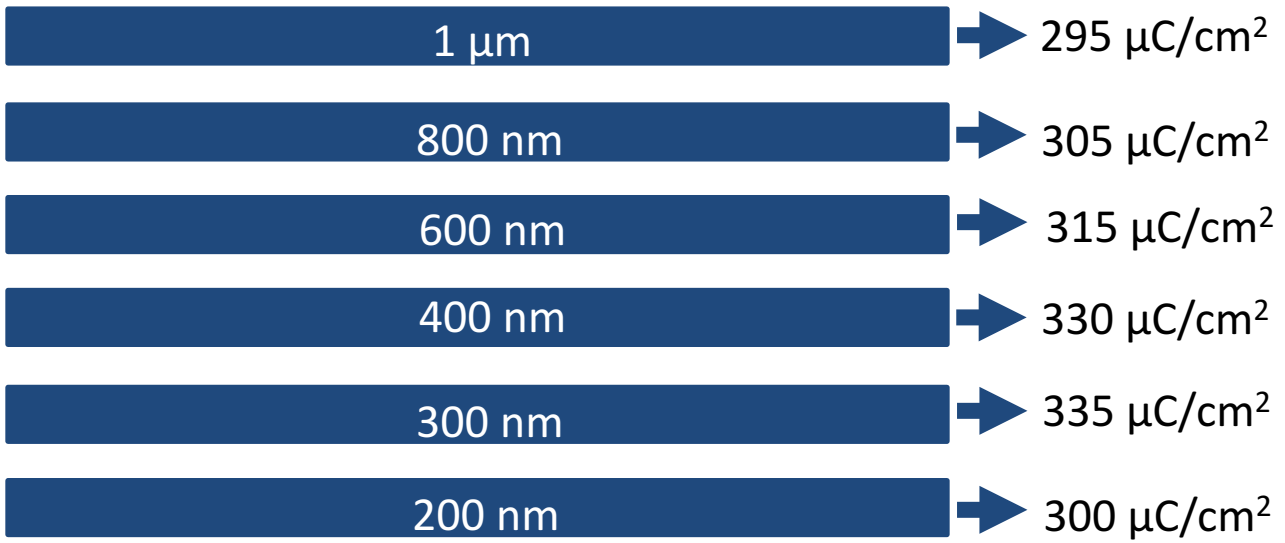
Wataru Nakagawa

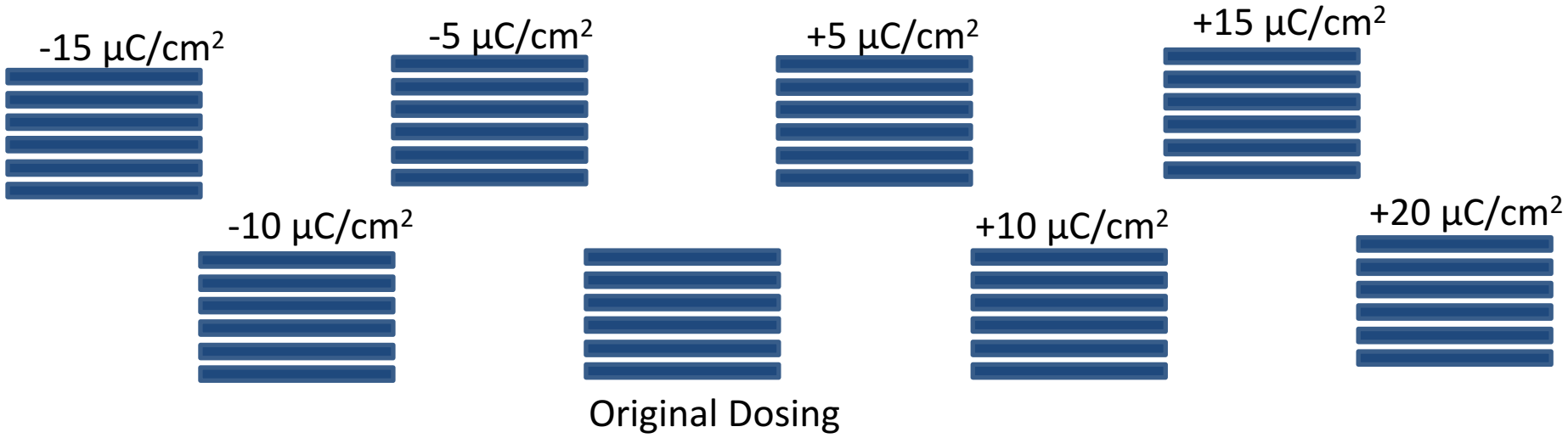
Optimization

- PMMA Development Time
- Primary E-Beam Dosage

Initial Dosing Trial

- Test trial conducted to find experimental dosing range central values
- 8 test gratings with dosing steps of 5 µC/cm^2, centered on original dosing values
- Original development times of 40 second PMMA and 100 second PMGI used

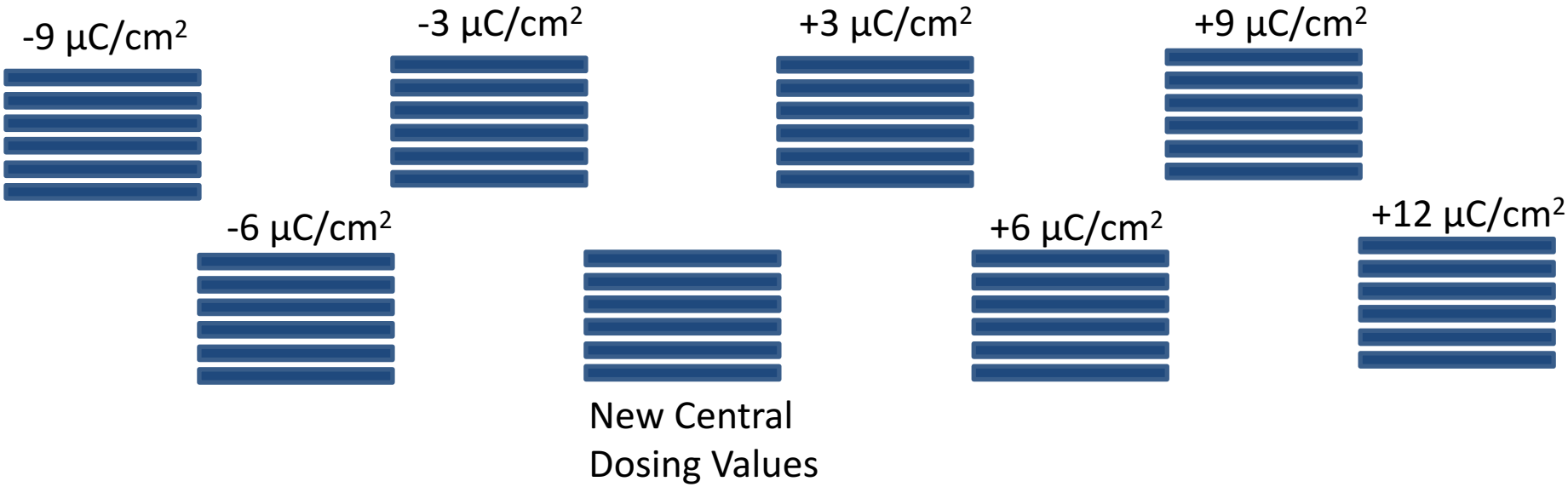




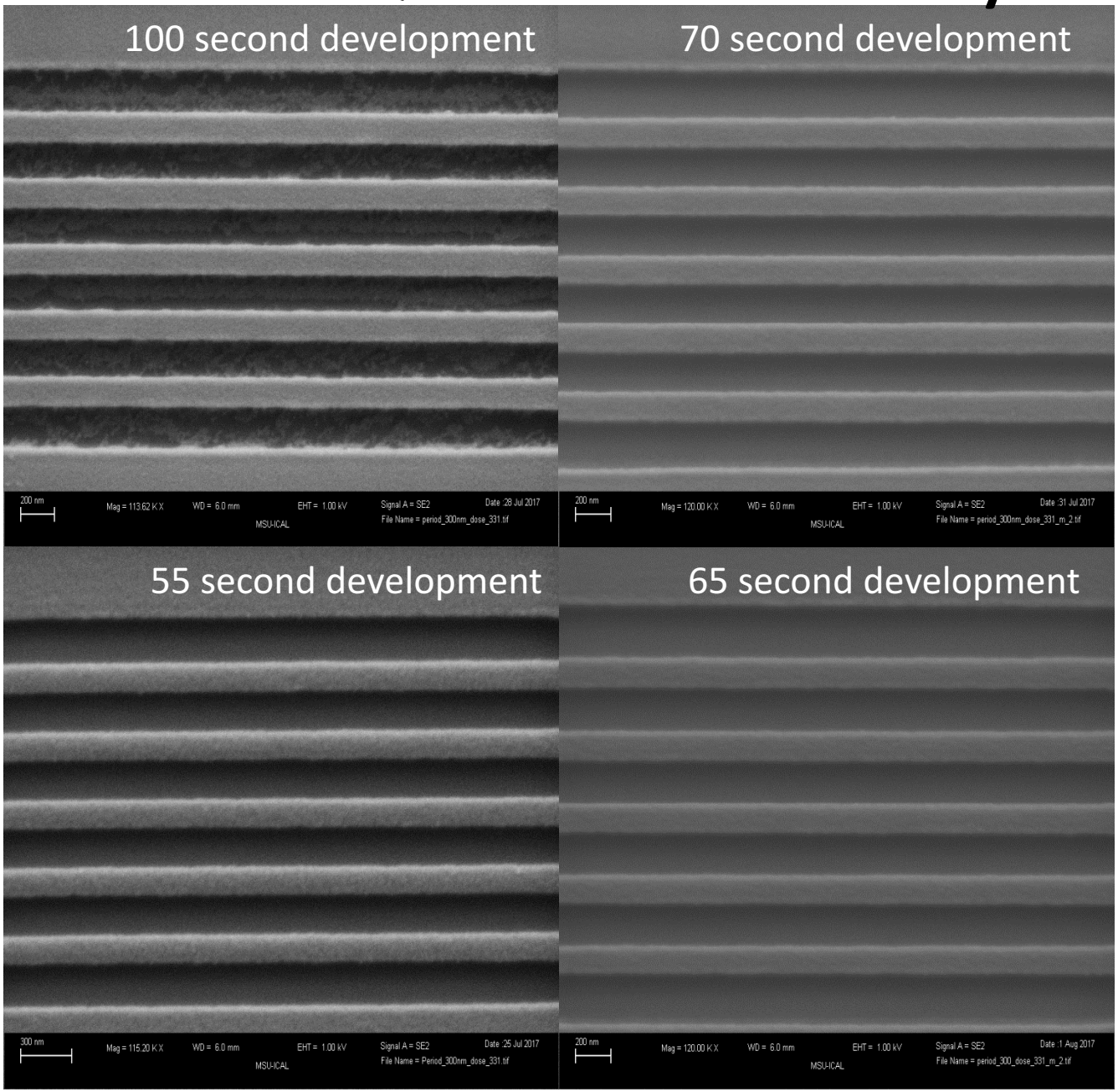
Optimization

Expected Period Size	New Central Dosing Values From Test Trial
1µm	300 µC/cm^2
800 nm	320 µC/cm^2
600 nm	320 µC/cm^2
400 nm	335 µC/cm^2
300 nm	340 µC/cm^2
200 nm	300 µC/cm^2

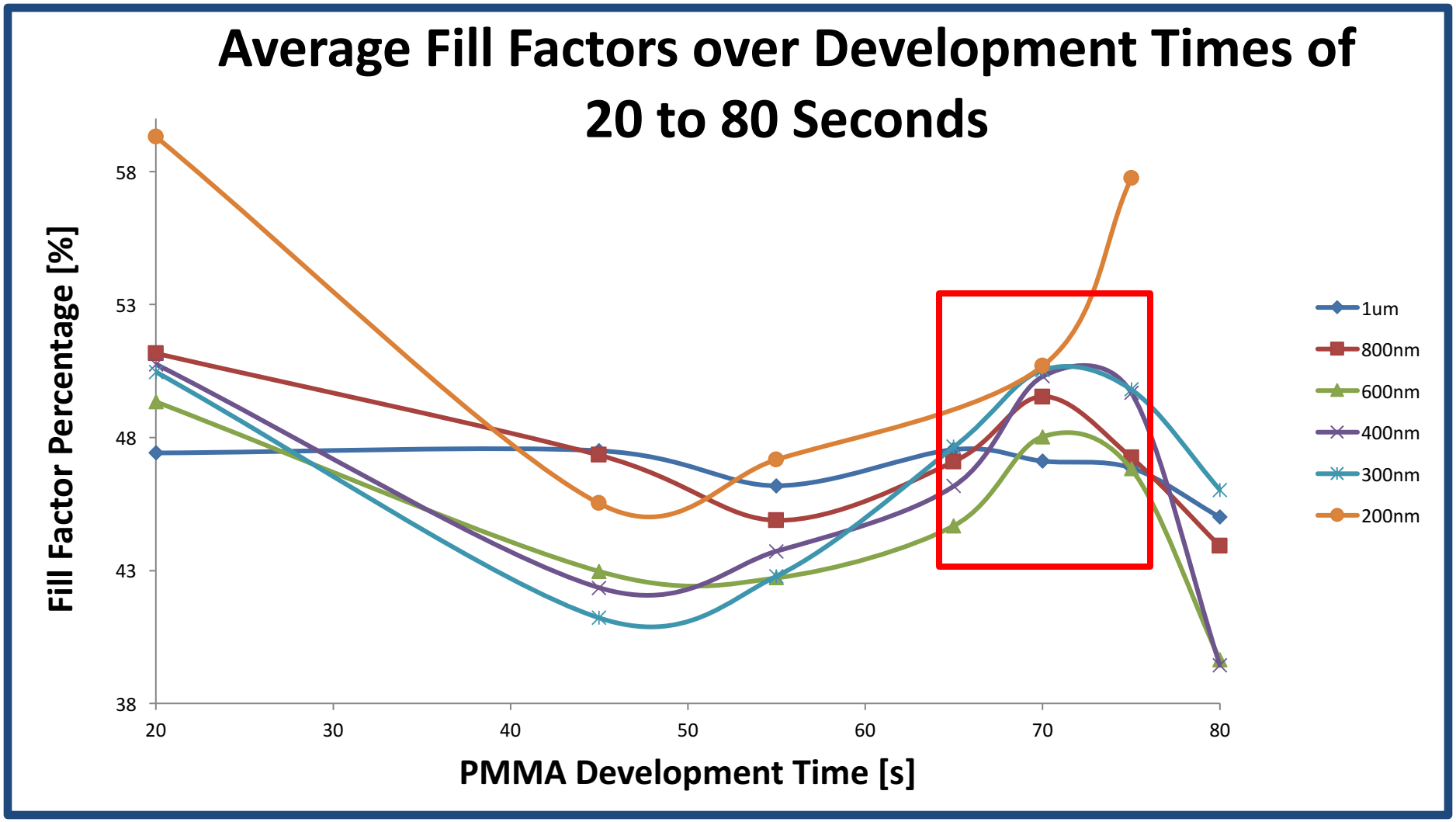
- New central dosing values chosen from test trial
- Gratings made with smaller dosing steps of 3 µC/cm^2
- PMMA development time varied from 20 to 100 seconds to find optimal dose and development time combination



Qualitative Analysis

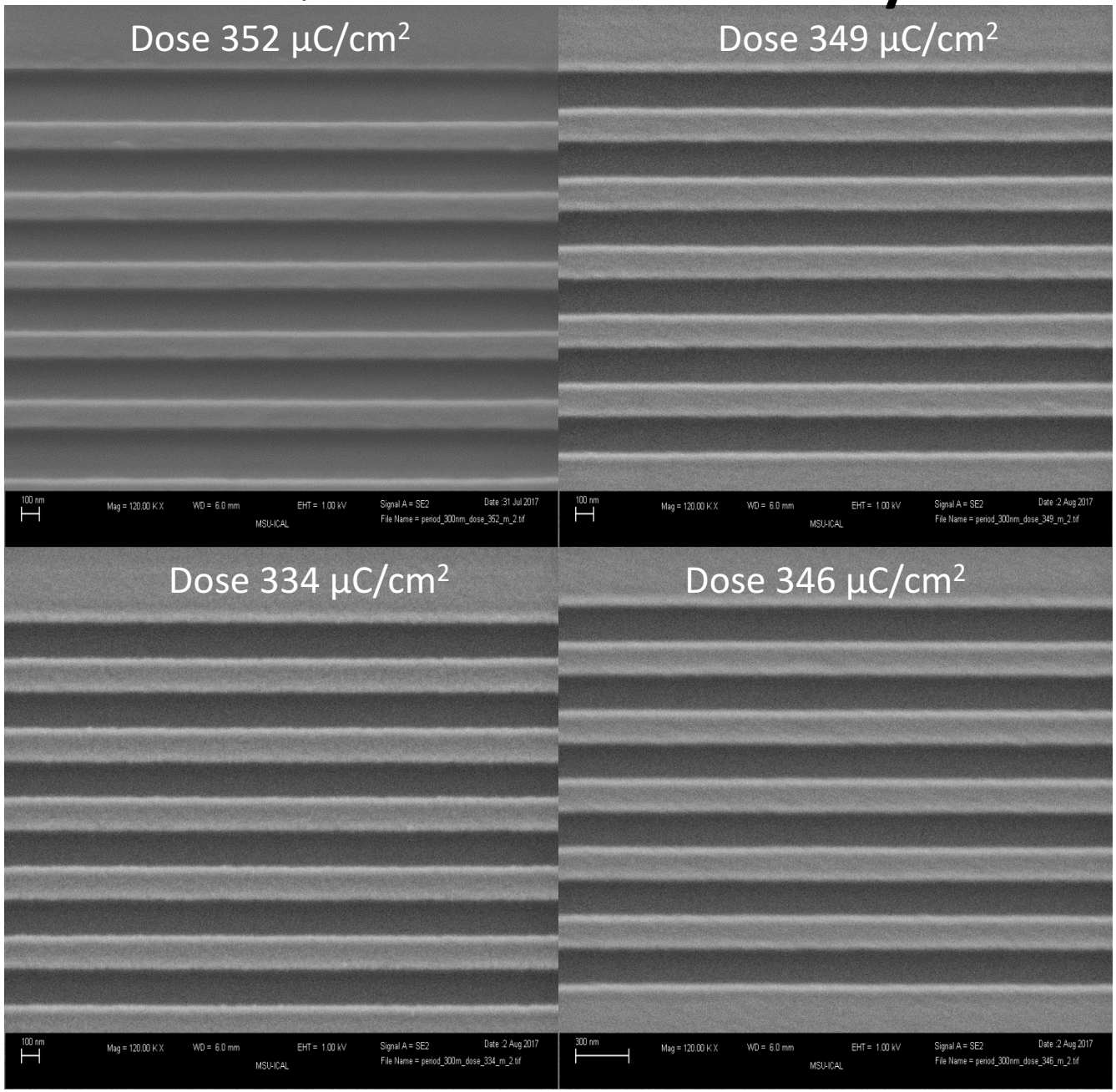


- All pictures 300 nm period, dose 331 $\mu C/cm^2$
- 70 and 65 second pictures have minimal edge roughness
- 55 second picture shows rough waving grating edges
- 100 second picture shows pitting and edge roughness from over development



- Lowest fill factor variation between all periods at 50% fill occurs at 70 second PMMA development time

Qualitative Analysis cont.



- All pictures 300 nm period, 70 second development time
- 349 µC/cm² and 346 µC/cm² pictures show gratings with straight edges and limited roughness
- 352 µC/cm² picture shows wavy grating edges
- 334 µC/cm² picture shows rough grating edges

Quantitative Analysis

Expected Period	E-Beam Dosing	PMMA Development Time	Measured Period	Measured Fill Factor
300 nm	346 $\mu C/cm^2$	70 sec	298.79	50.02%
300nm	343 $\mu C/cm^2$	70 sec	297.22 nm	45.88%
300nm	349 $\mu C/cm^2$	70 sec	298.48 nm	51.47%
300nm	346 $\mu C/cm^2$	65 sec	298.48 nm	44.38%
300nm	346 $\mu C/cm^2$	75 sec	297.61 nm	48.59%

Quantitative Analysis Cont.

Expected Period	E-Beam Dosing	PMMA Development Time	Measured Period	Measured Fill Factor
800nm	323 $\mu C/cm^2$	70 sec	760.77 nm	50.03%
800nm	320 $\mu C/cm^2$	70 sec	763.02 nm	49.93%
800nm	326 $\mu C/cm^2$	70 sec	766.72 nm	50.63%
800nm	323 $\mu C/cm^2$	65 sec	758.60 nm	48.25%
800nm	323 $\mu C/cm^2$	75 sec	762.20 nm	48.05%

Results

Expected Period Size	Optimal Dosing Value	Measured Period	Measured fill factor
1µm	306 µC/cm^2	992.7 nm	51.82%
800 nm	323 µC/cm^2	760.77 nm	50.03%
600 nm	323 µC/cm^2	574.48 nm	48.15%
400 nm	341 µC/cm^2	395.2 nm	48.58%
300 nm	346 µC/cm^2	298.79 nm	50.02%
200 nm	309 µC/cm^2	201.62 nm	51.89%

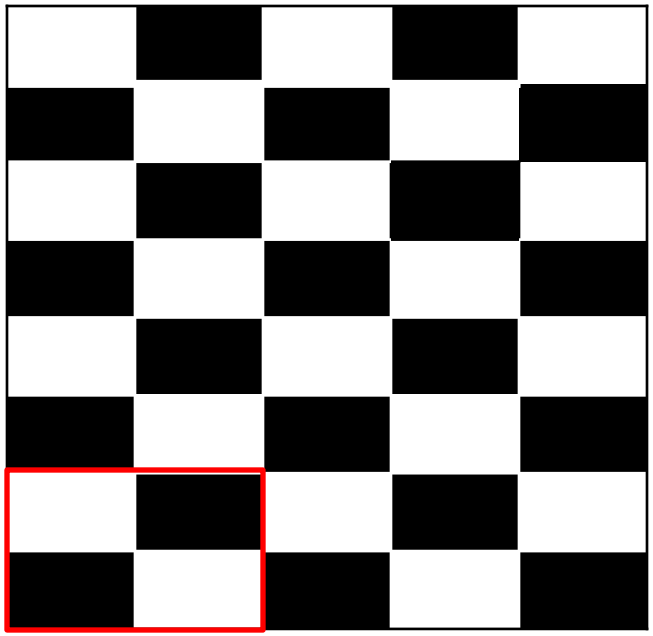
Conclusions

- Found optimal PMMA development time at 21° C
- Found optimal dosing values for grating periods ranging from 1 µm to 200 nm at a 70 second PMMA development time

Next Steps

- Vary PMGI Development time
- Modu Lab Deposition Optimization

Ultimate Application



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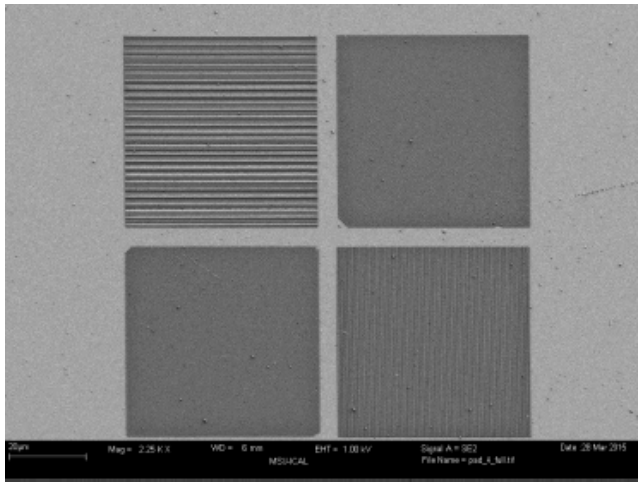
Polarizer Array

wmocloudatlas.org



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