Optimization Studies of ZEP520

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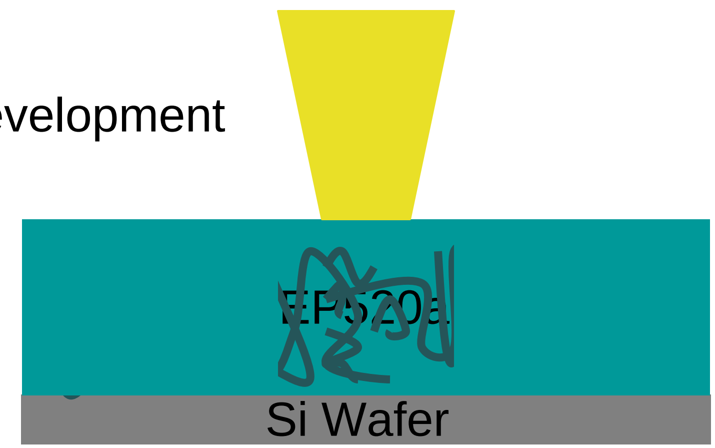
Objective

- To learn how to optimize the resolution of ZEP520 by:
  - Reviewing contrast curves
  - Looking at how resist thickness changes sensitivity
  - Changing development conditions
- To better understand how developing under different temperatures effects the contrast, sensitivity, and resolution of the resist.

Introduction to ZEP520

- ZEP520 is a common, commercial available positive tone, polymer resist
  - When electrons hit the resist, chain scission occur which allows the exposed resist to be dissolved in the developer[1-2,4-5]

Post Development



Introduction to ZEP520

- Advantages of ZEP520a
  - Good resolution, high contrast[1-3]
  - Short write time (3 times faster than PMMA) [3]
  - Good etch resistance[3]
- Disadvantages of ZEP520a
  - Resolution of PMMA is better[3]

Introduction to Resist Enhancement

- To improve the contrast, the steepness of the sidewalls, and to limit the sidewall roughness, one can limit the chains that dissolve to only the very smallest chains, the chains that were directly hit by the beam[2].
- Two ways to modify size of chains dissolved:
    - change developer, i.e. dilute the developer or use a different developer all together[1]
    - change develop conditions, for example at colder temperatures the developer doesn't dissolve the resist as effectively[1]

Process Conditions

- <u>substrate:</u>
  - 4” silicon wafer, coated first, then snap cleaved into pieces

- <u>coat:</u>
  - 60nm thick resist
    - 3:1 ratio of Anisole to ZEP520A resist
    - 2000 RPM, 1000 RPM / sec, 60sec
  - 35nm thick resist
    - 4:1 ratio of Anisole to ZEP520A resist
    - 4000 RPM, 2000 RPM / sec, 60sec
  - 180C hot plate bake, 2 min

- <u>expose:</u>
  - 2 nA, 100 kV, 6nm shot pitch
  - dose varied, subsequent slides indicate dose
- <u>develop:</u>
  - amyl acetate, 30sec or 2min, at room temperature, 0˚C or 10˚C
  - IPA, 30 sec, immersion
  - N2 blow dry

Contrast Experiments

- Usually, a set of 20 squares where the dose of each square varies about 5% from one to the next
  – Varied from 70 to 250 uC/cm^2
- Varied development conditions including duration and temperature
- Measured resist left in the square
  – Nanospec Refactometer
  – Plot dose vs resist thickness

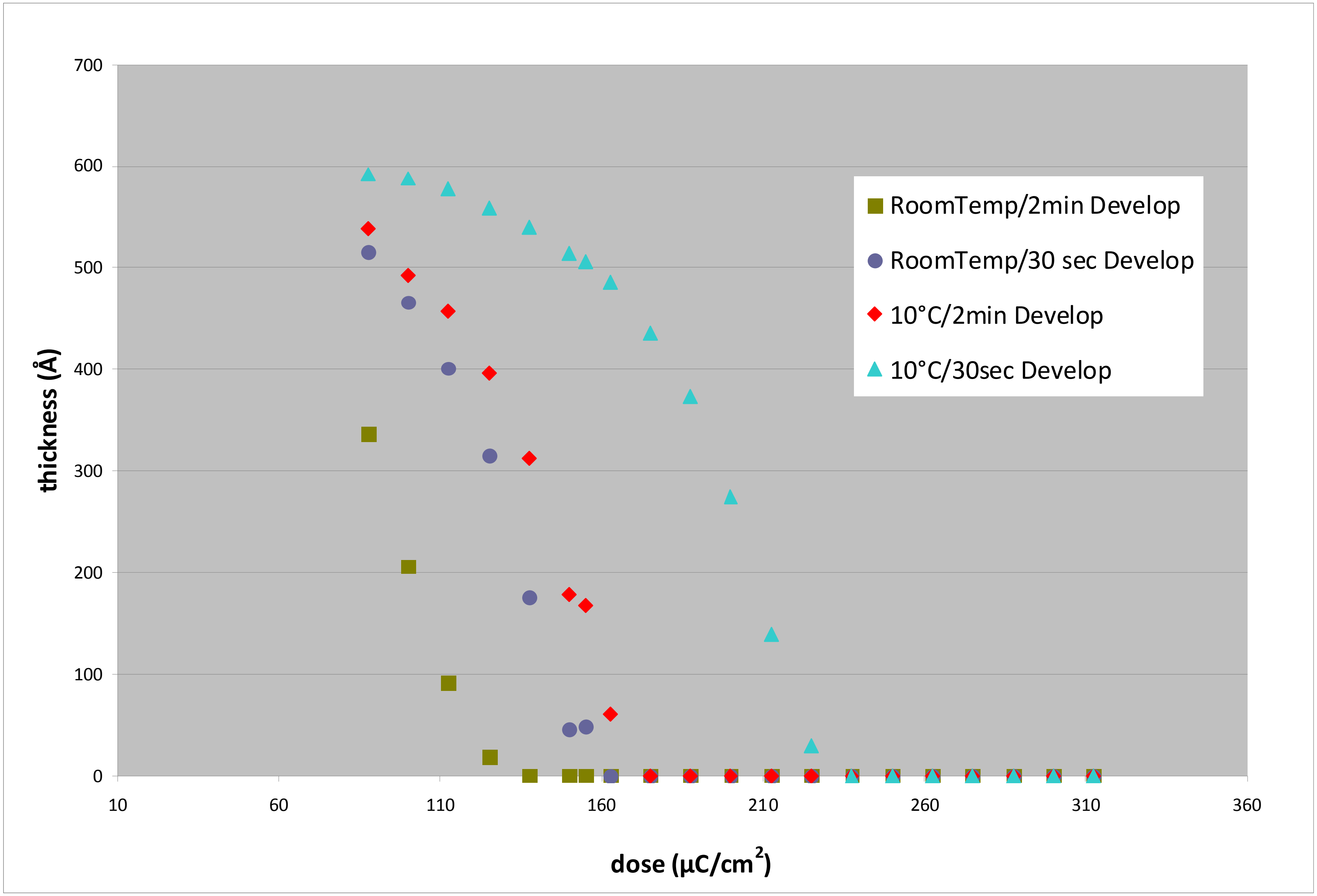
Contrast Experiments

- Contrast is calculated by the data collected
- For a positive resist, it is calculated with this equation:

$$\gamma = \frac{1}{\log\left(\frac{D_{100}}{D_0}\right)}$$

  - D_0 is the dose just before resist begins to be removed
  - D_{100} is the smallest dose where there is no more residue

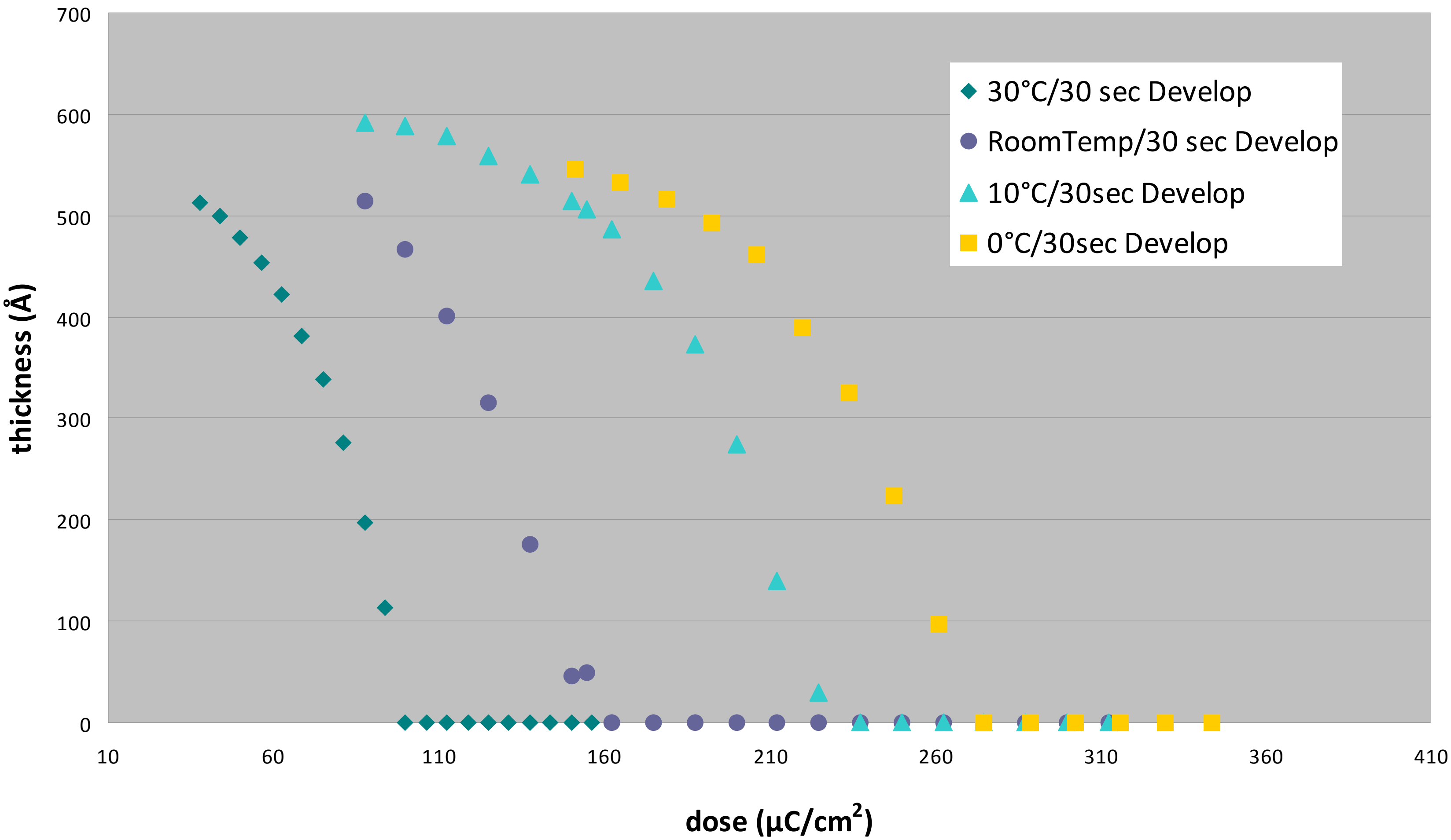
Comparing Different Temperature and Different Durations of Development



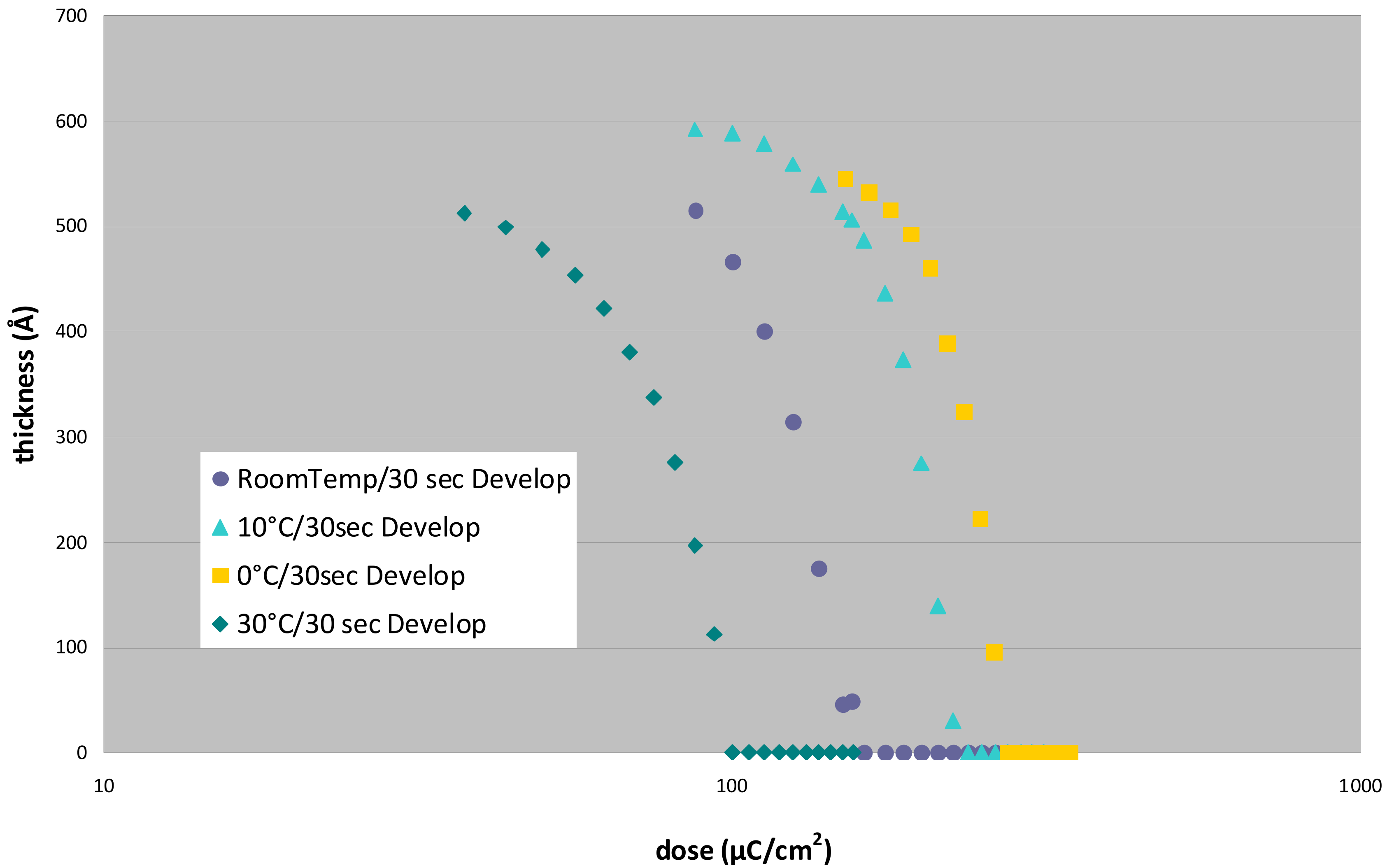
Comparing Different Temperature and Different Durations of Development

- This graph illustrates that with longer development the sensitivity increase
  - This could be expected because a longer development would mean more resist is stripped
- It also shows lowering the temperature decreases the resist sensitivity
  - At lower temperatures the resist is less effective because there is less molecular motion
  - Therefore, a larger dose is required to strip the same resist thickness

Comparing Different Temperature of Development



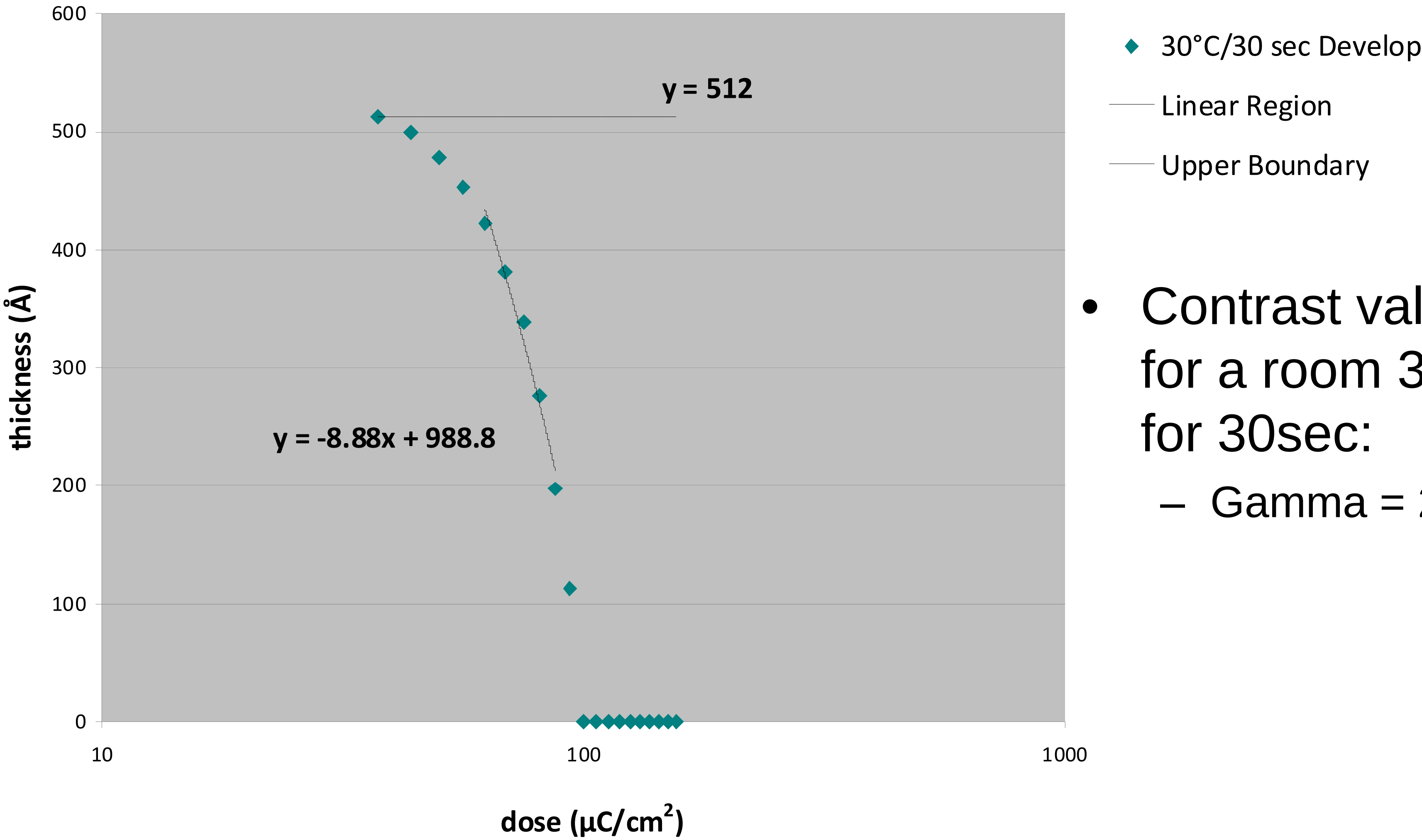
Logarithmic Comparison of Different Temperature Developments



Comparing Different Temperature of Development

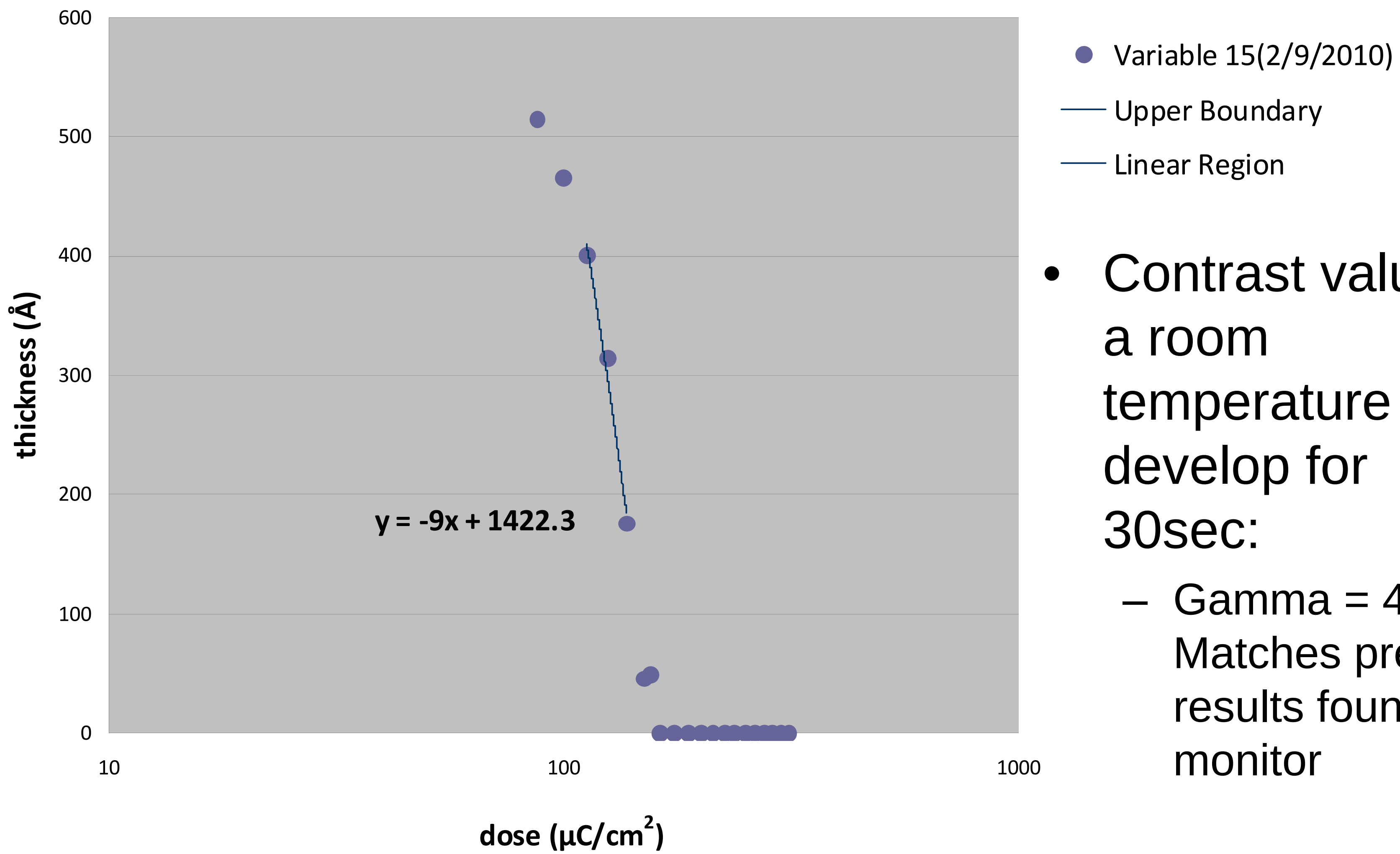
- This data shows:
  - A decrease in sensitivity with decreased development temperature
  - As the temperature decreases the linear region of the graph becomes steeper
    - More evident in log plot
    - Indicates a higher contrast value
  - For 30°C, room temperature, 10°C, and 0°C development, the first doses to clear all the resist are 100, 160, 240, and 275 um/cm^2, respectively

Contrast Curve 30°C Develop



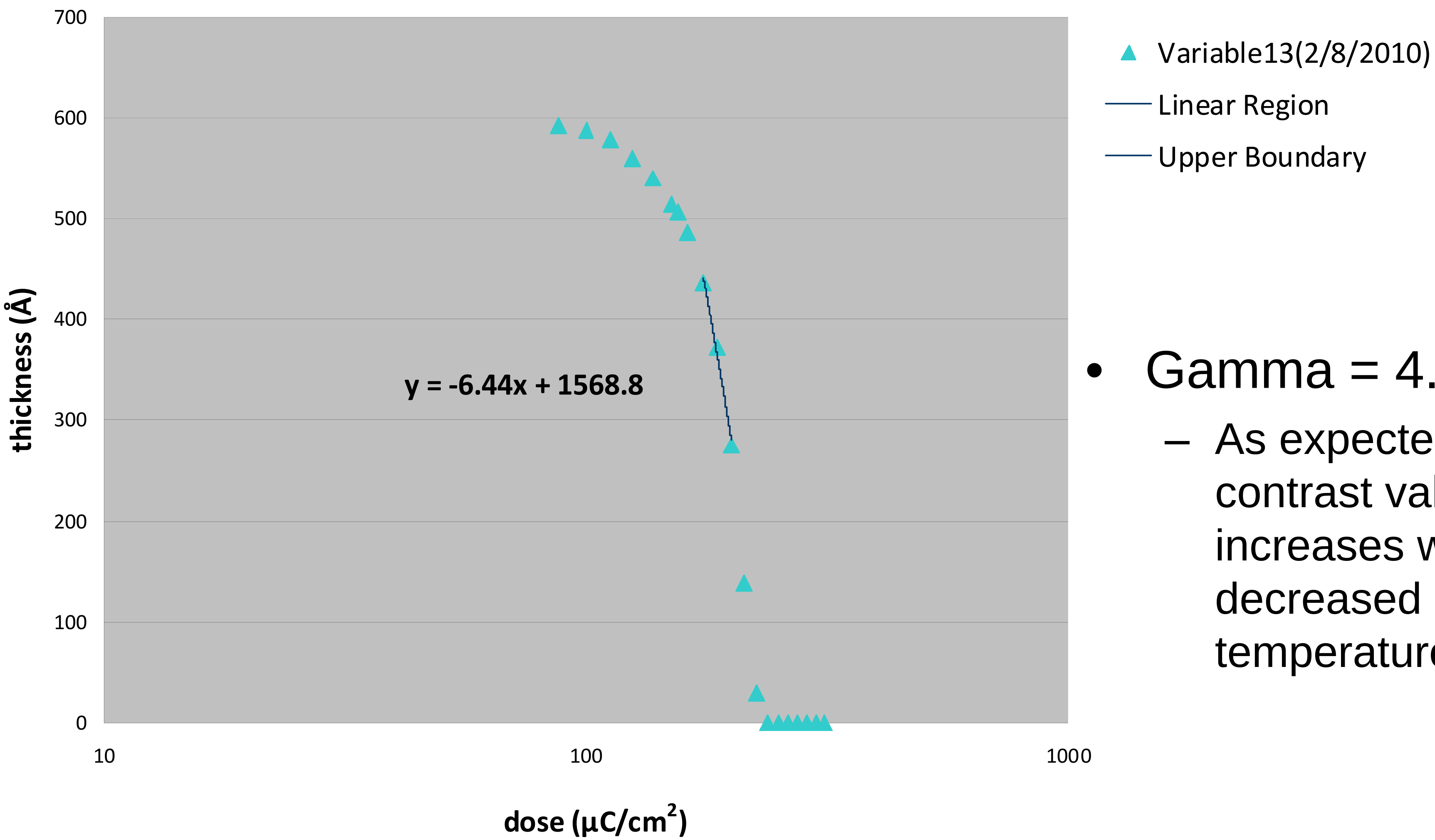
- Contrast value for a room 30° for 30sec:
  - Gamma = 2.79

Contrast Curve Room Temperature Develop



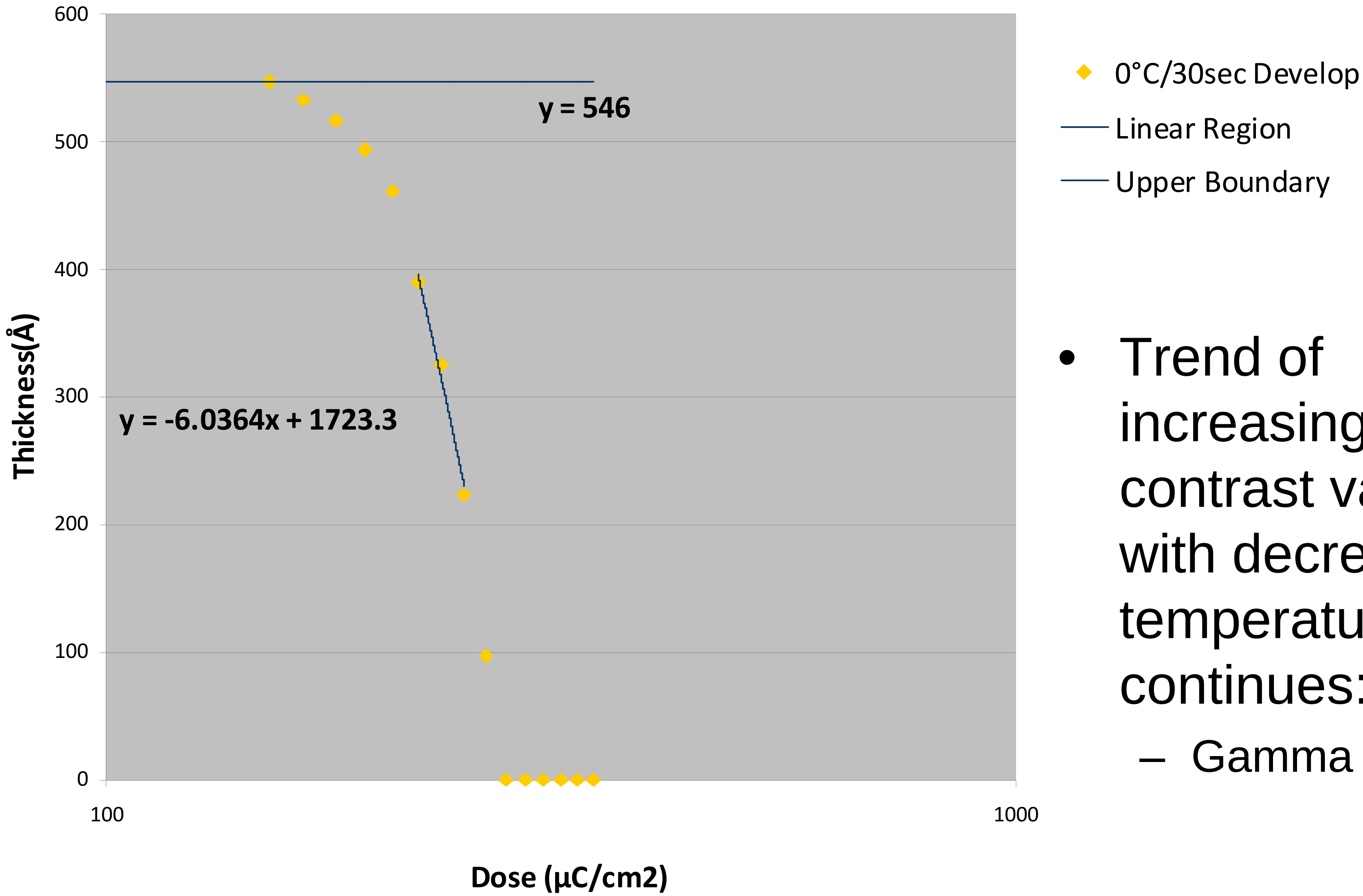
- Contrast value for a room temperature develop for 30sec:
  - Gamma = 4.28 Matches previous results found in monitor

Contrast Curve for 10°C Develop



- Gamma = 4.79
  - As expected, contrast value increases with decreased temperature

Contrast Curve for 0°C Develop

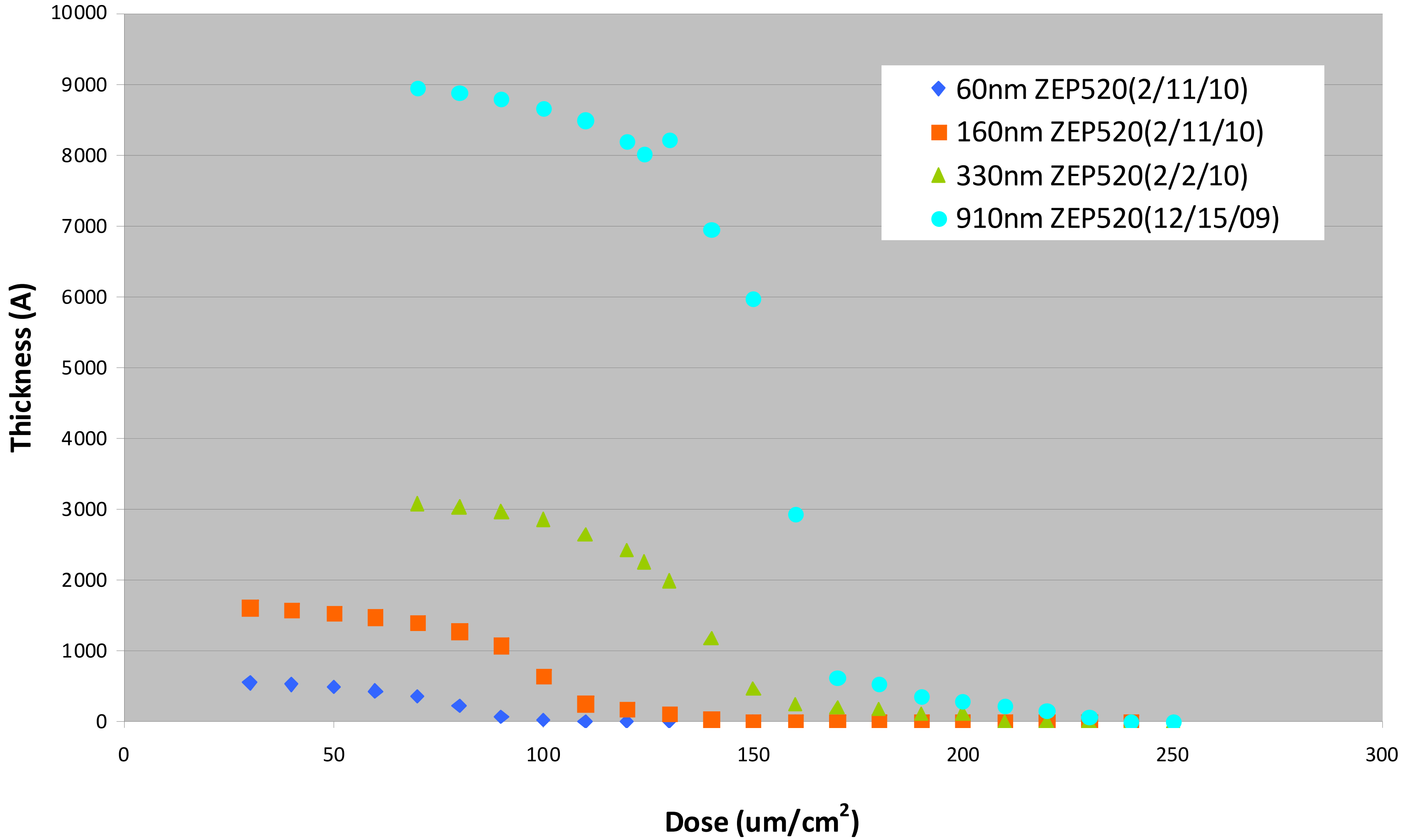


- Trend of increasing contrast values with decreasing temperatures continues:
  - Gamma = 6.03

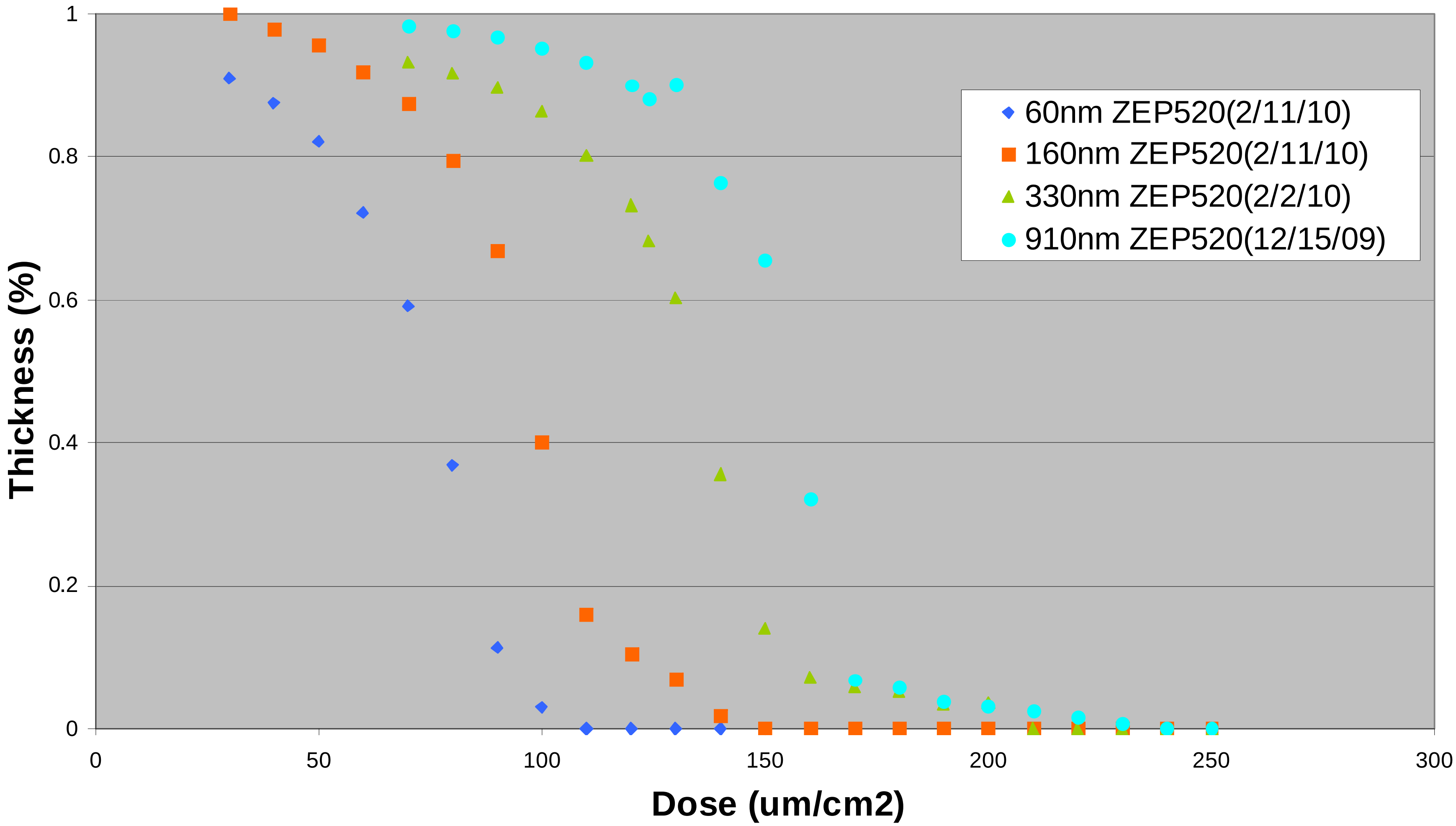
Thickness to Sensitivity Experiments

- Exposed same boxes used to calculate the contrast, but varied the resist thickness
  - 60nm, 160nm, 330nm, 9100nm
- Plotted dose vs. thickness, again
  - Also plotted a normalized version, where the thickness was divided by the original resist height.

Comparing Thickness to Sensitivity Contrast Curves

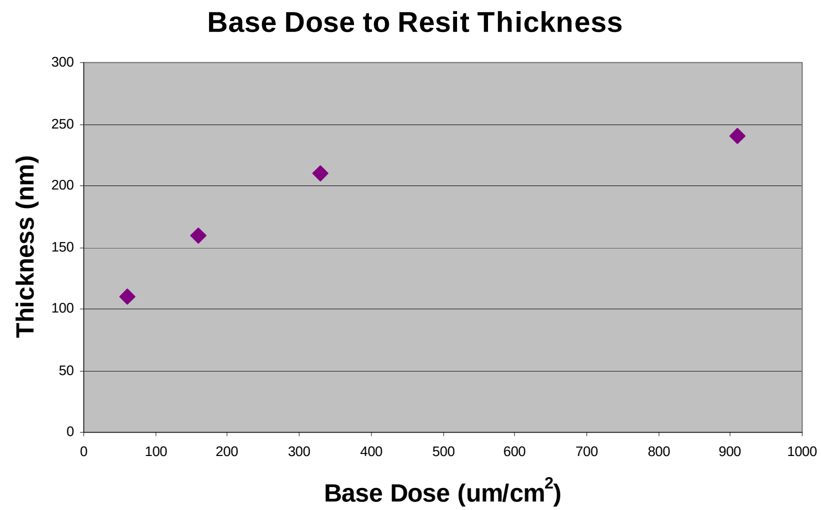


Comparing Thickness to Sensitivity Normalized Contrast Curves



Comparing ZEP520 Thickness to Sensitivity Contrast Curves

- Dose needed increases as the original thickness of the ZEP increases
  - Not linear

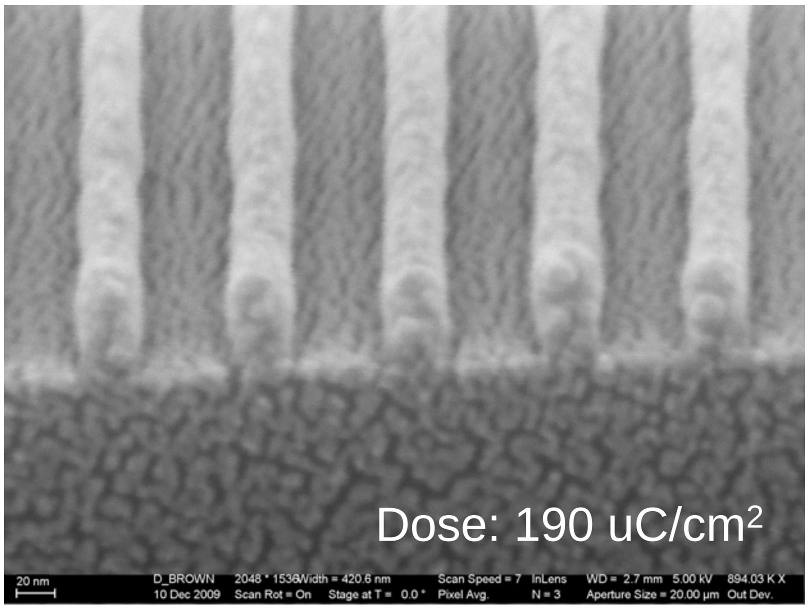


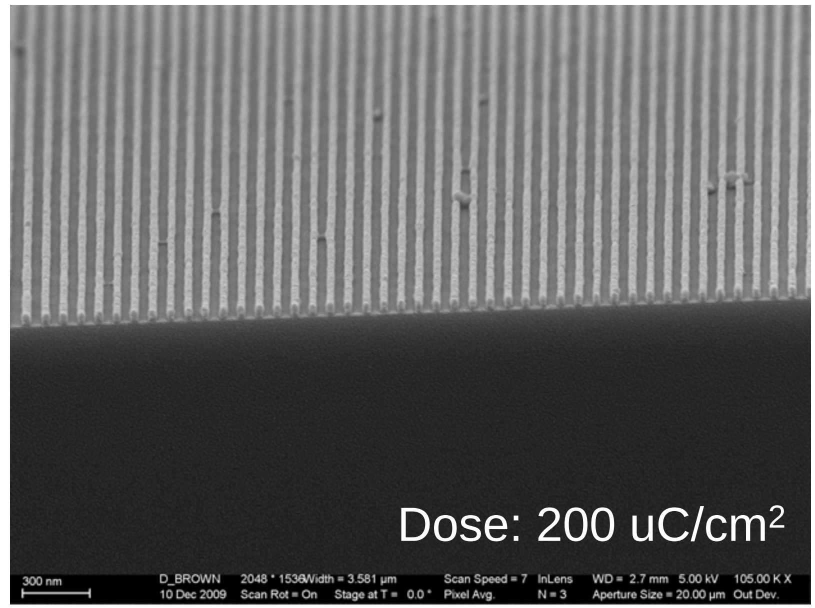
- Base dose corresponding to original resist thickness
  - 60nm: 110uC/cm^2
  - 160nm: 160uC/cm^2
  - 330nm: 210uC/cm^2
  - 910: 240/uC/cm^2

Minimizing Line and Space Pattern Size Experiments

- Pattern sets of 20nm, 30nm, and 40nm line and space
- Developed lines for 30 seconds in Amyl Acetate
  - At temperatures of 0˚C, 10˚C and room temperature
  - Bathed in IPA to stop develop
- Snap cleaved through the middle of the lines and coated with hummer
- Examined cross sections with an SEM
  - LEO 1530 or Zeiss Ultra 360

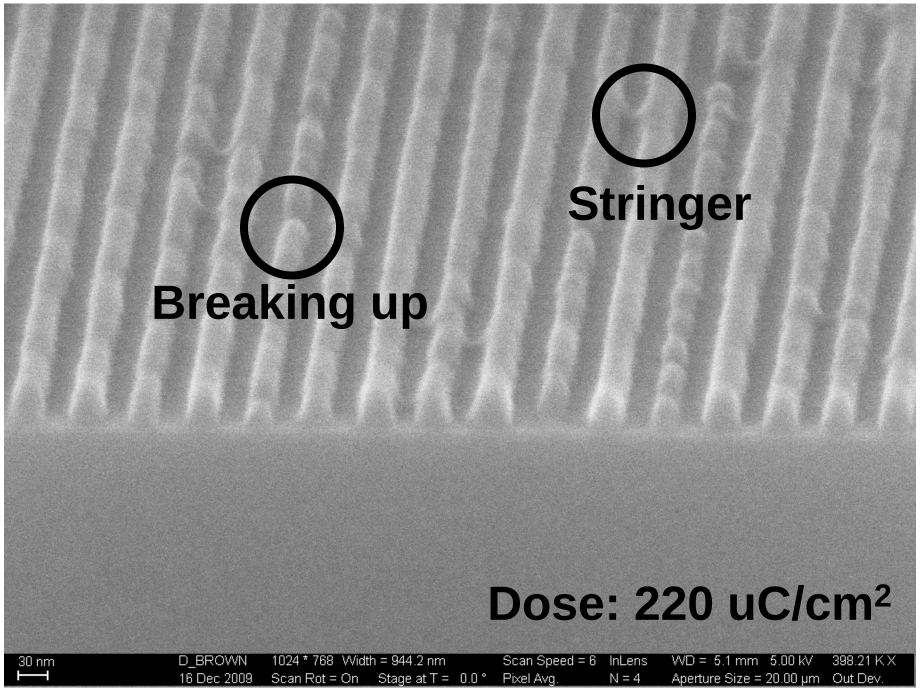
40nm L/S with Room Temperature Develop

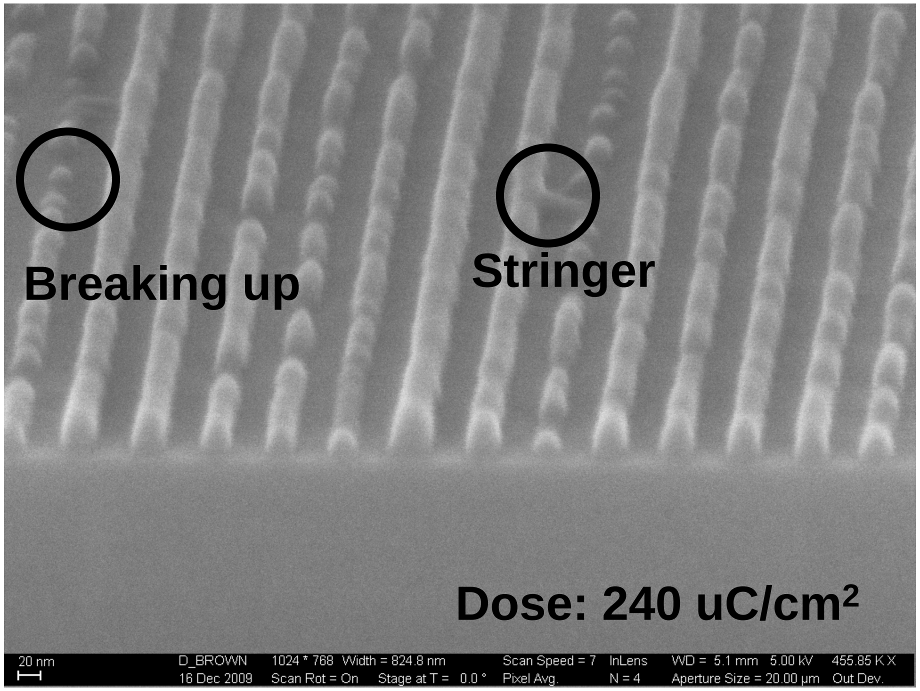




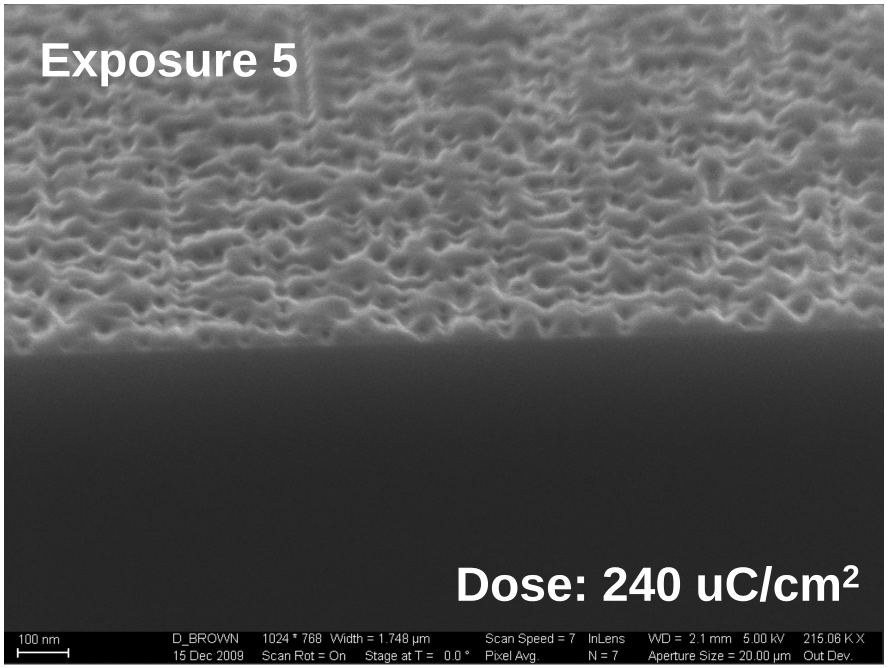
- Starting point
- What the machine and the resist are capable with out too much effort

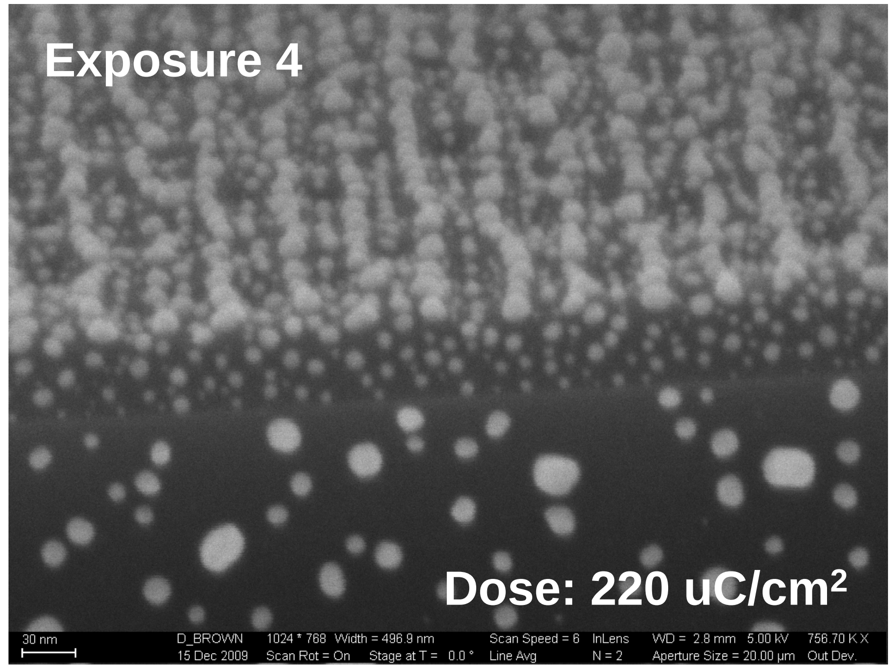
30nm L/S with Room Temperature Develop





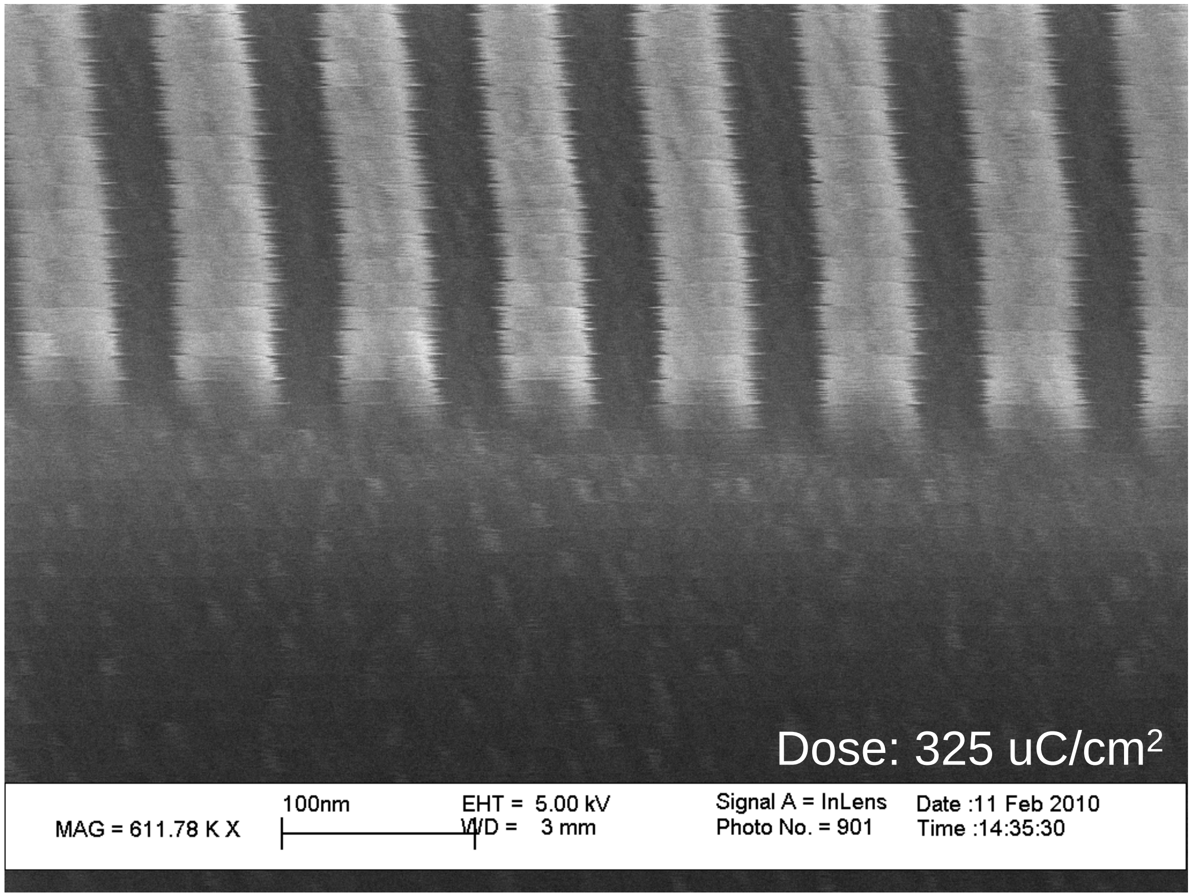
20nm L/S with Room Temperature Develop



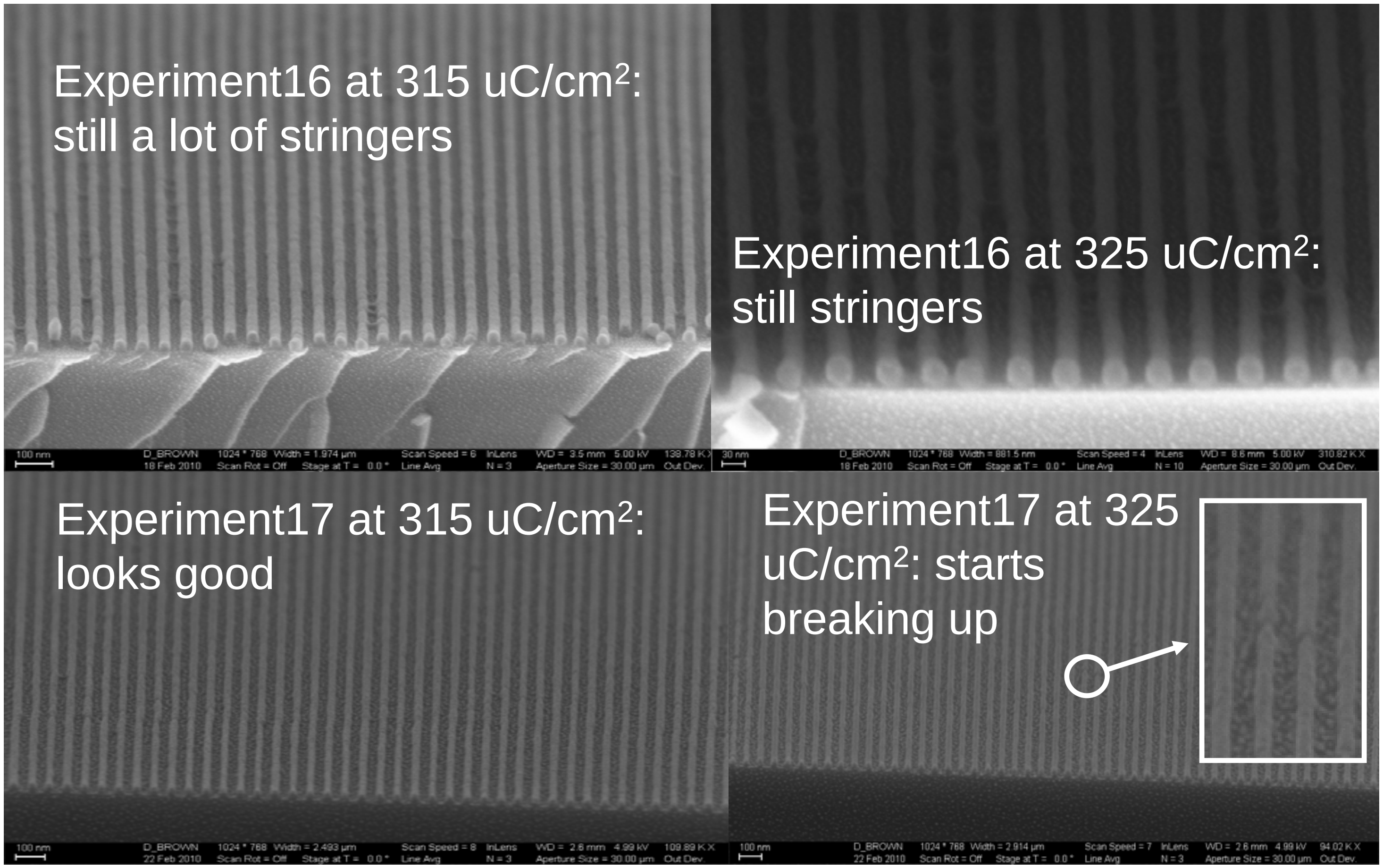


- No good result were obtained
  - The resist goes straight from under developed to breaking up.

40nm L/S with 10°C Develop

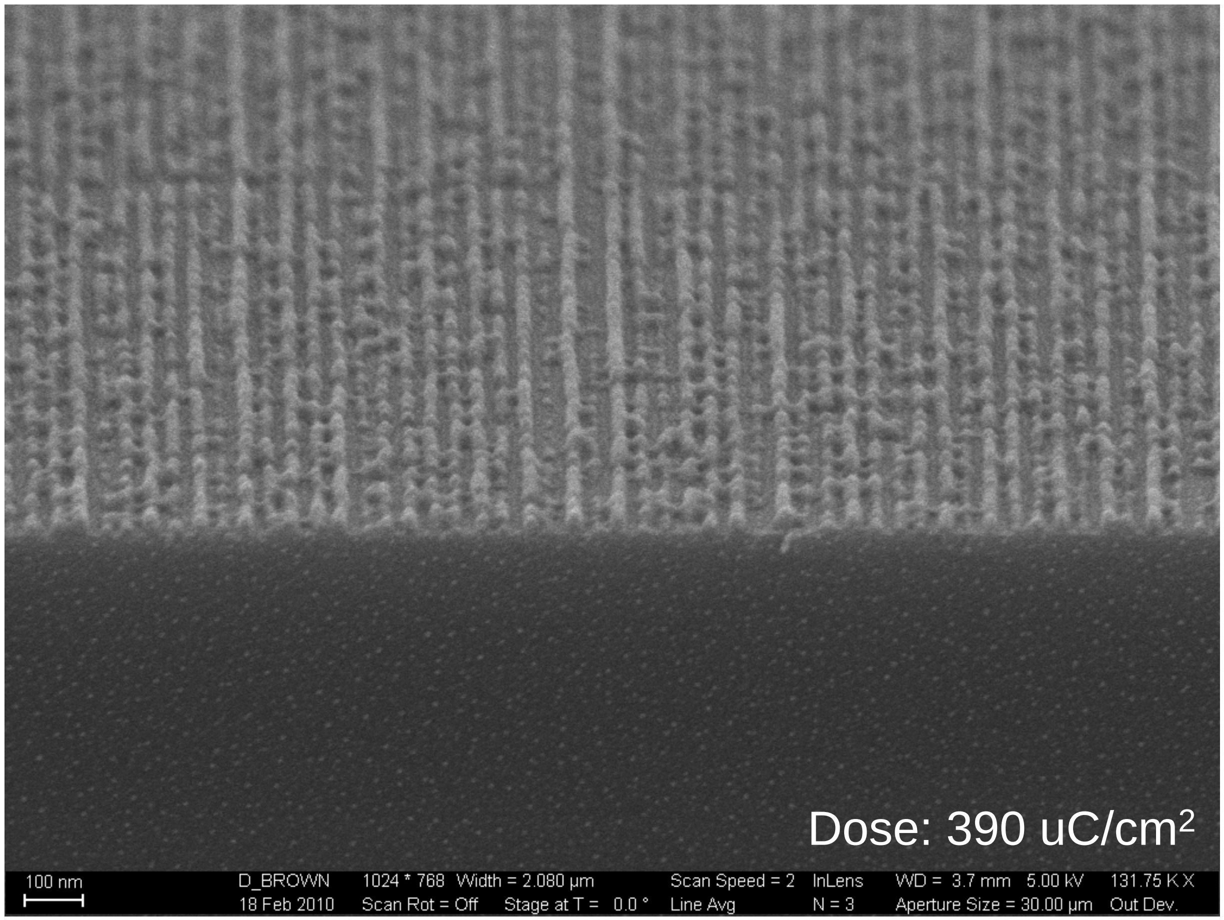


30nm L/S with 10°C Develop

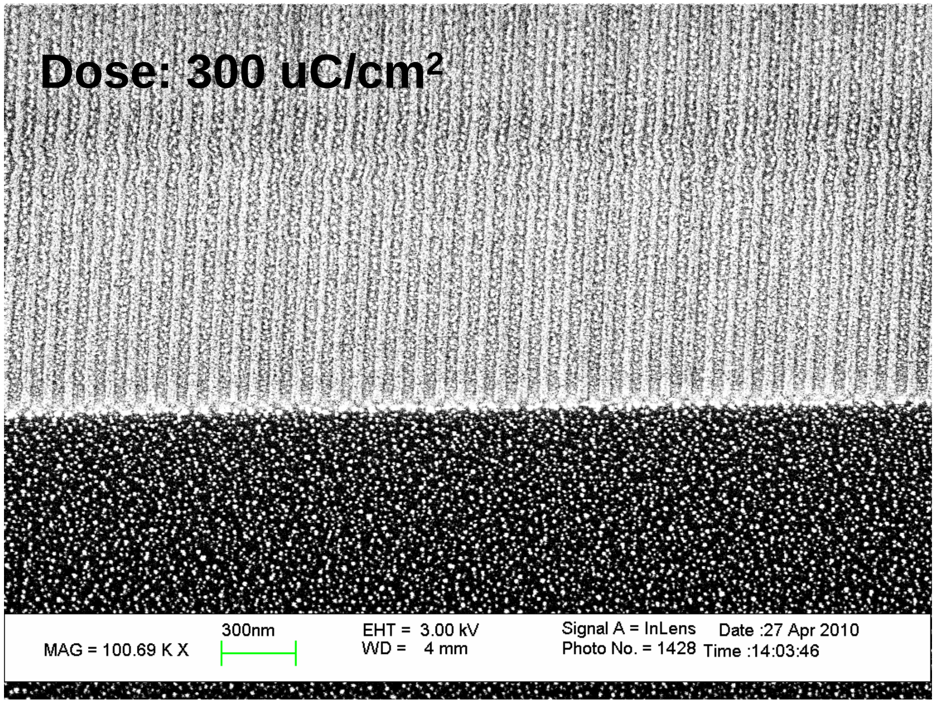


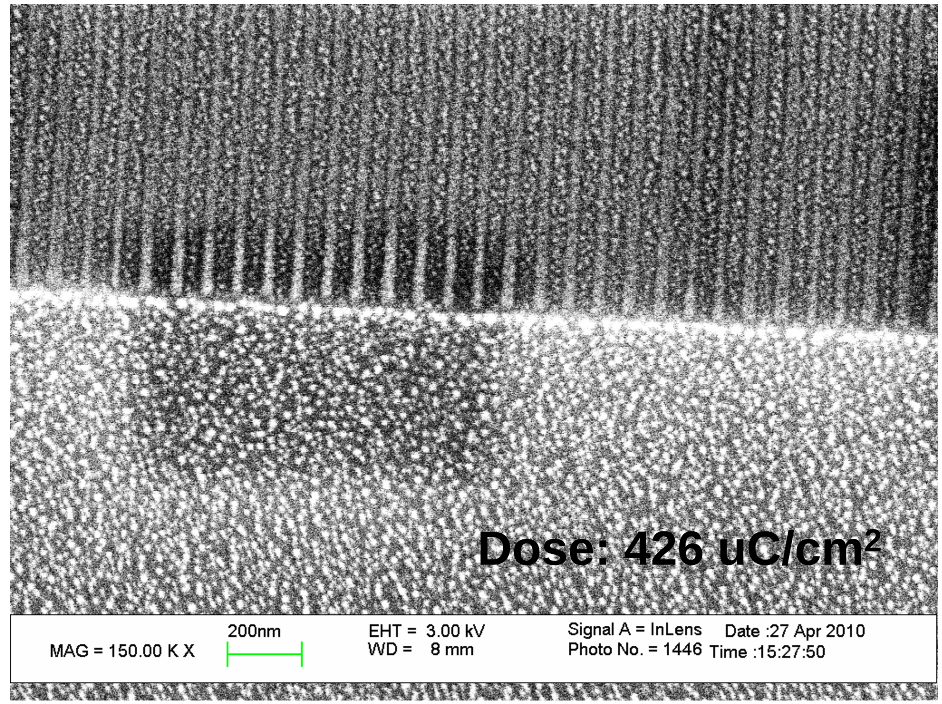
- Getting ok results form experiment to experiment, but not consistent

20nm L/S with 10°C Develop



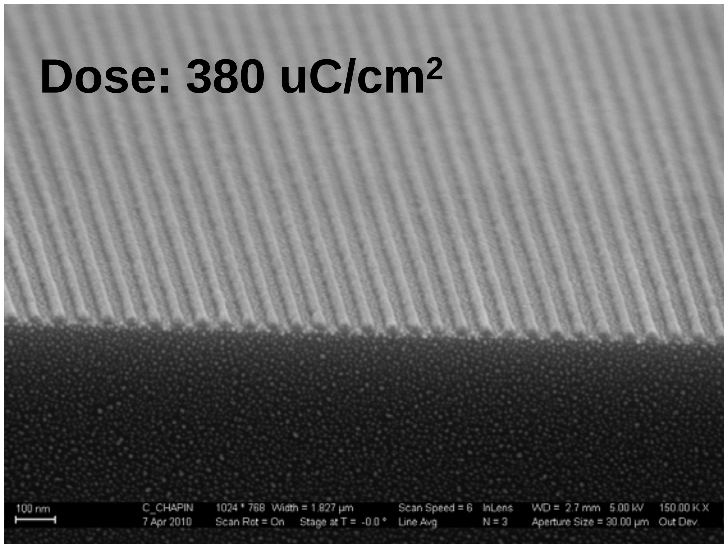
40nm L/S with 0°C Develop

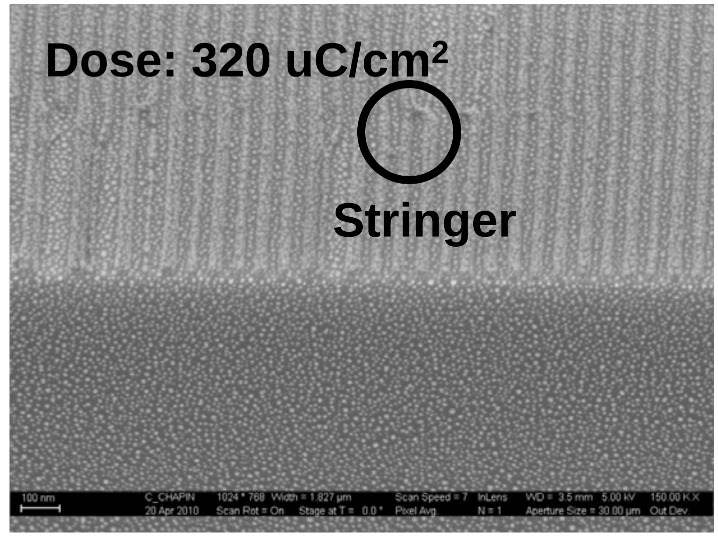


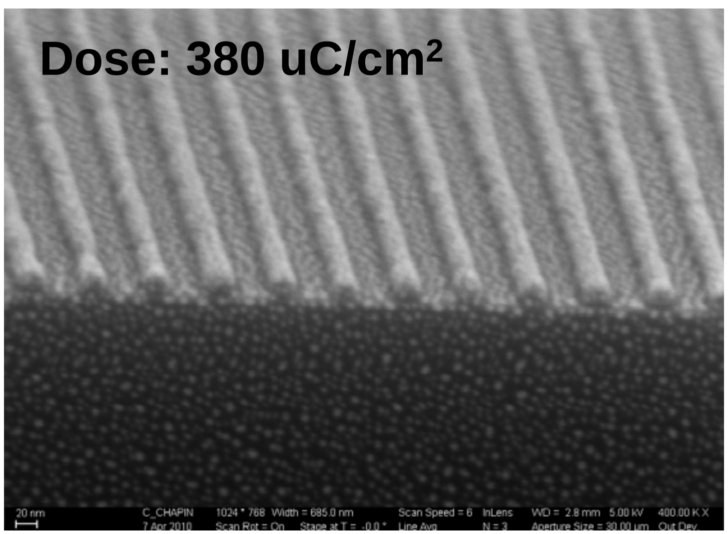


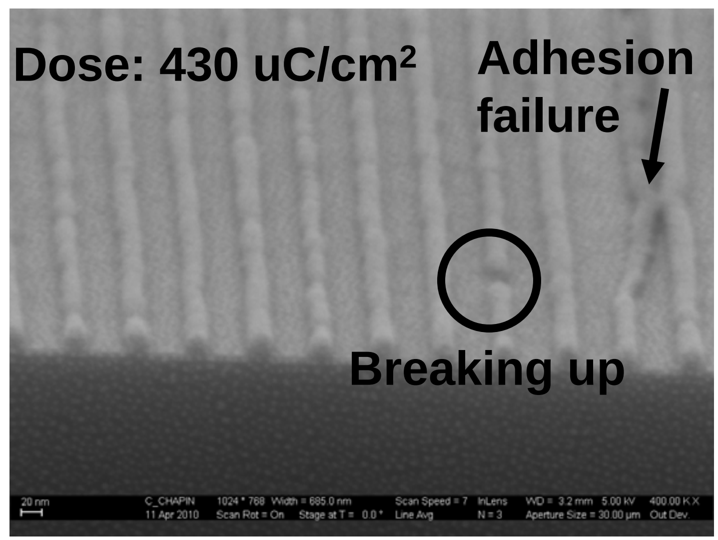
- Very large dose range for clear lines without breaking and without stringers

30nm L/S with 0°C Develop

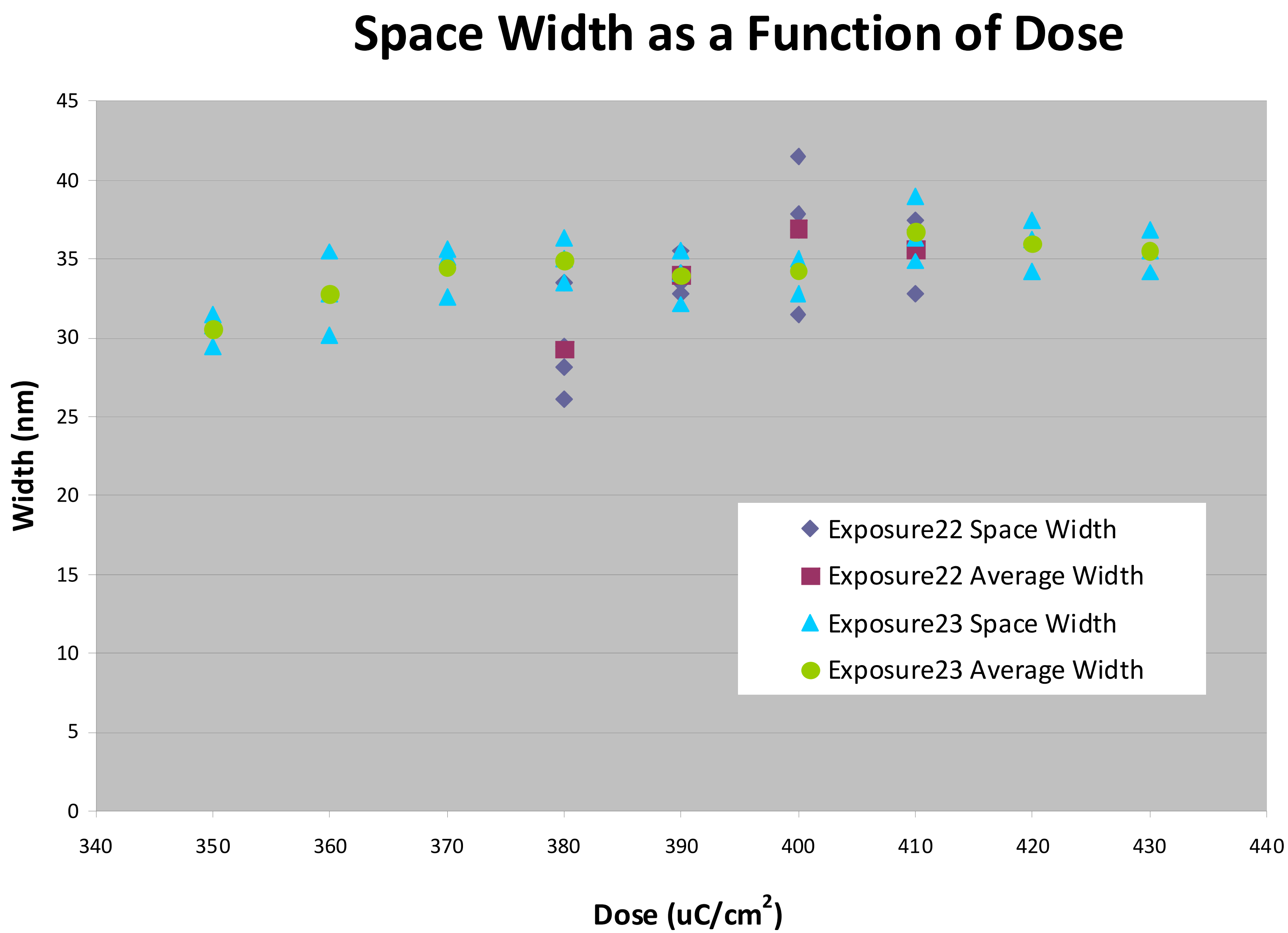




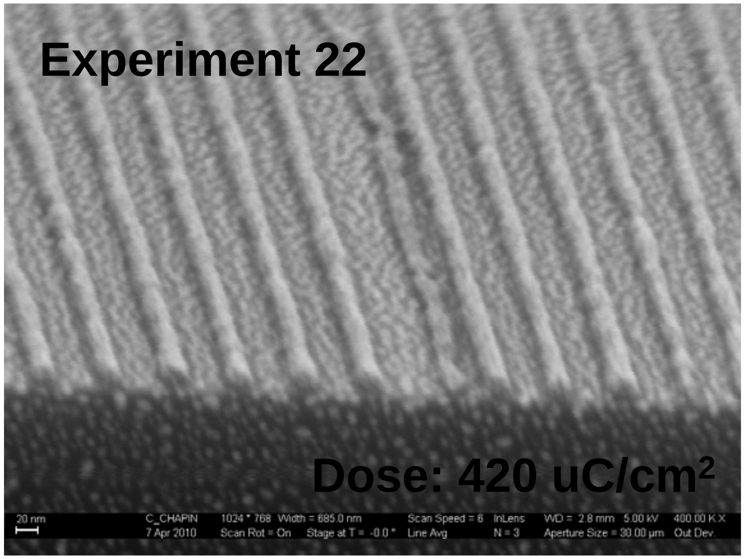


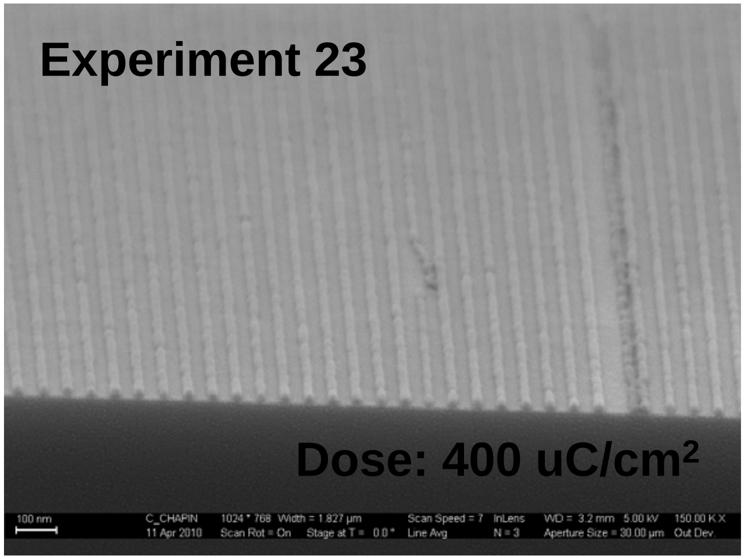


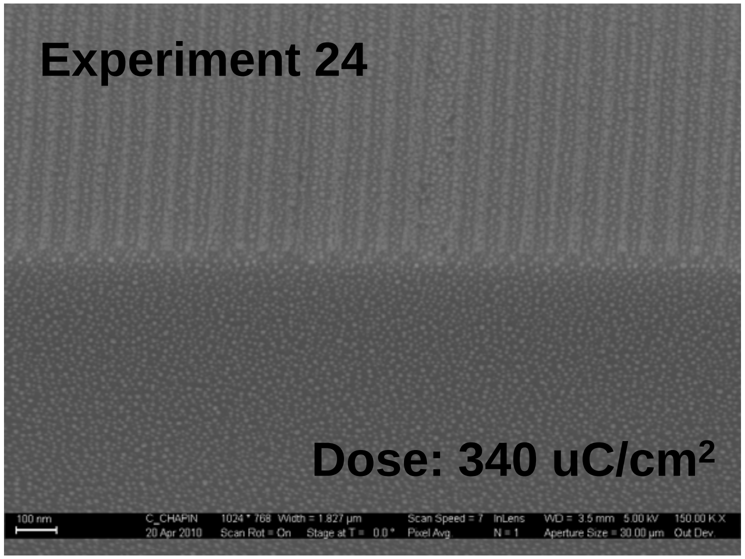
30nm L/S with 0°C Develop



30nm L/S with 0°C Develop Adhesion Failure

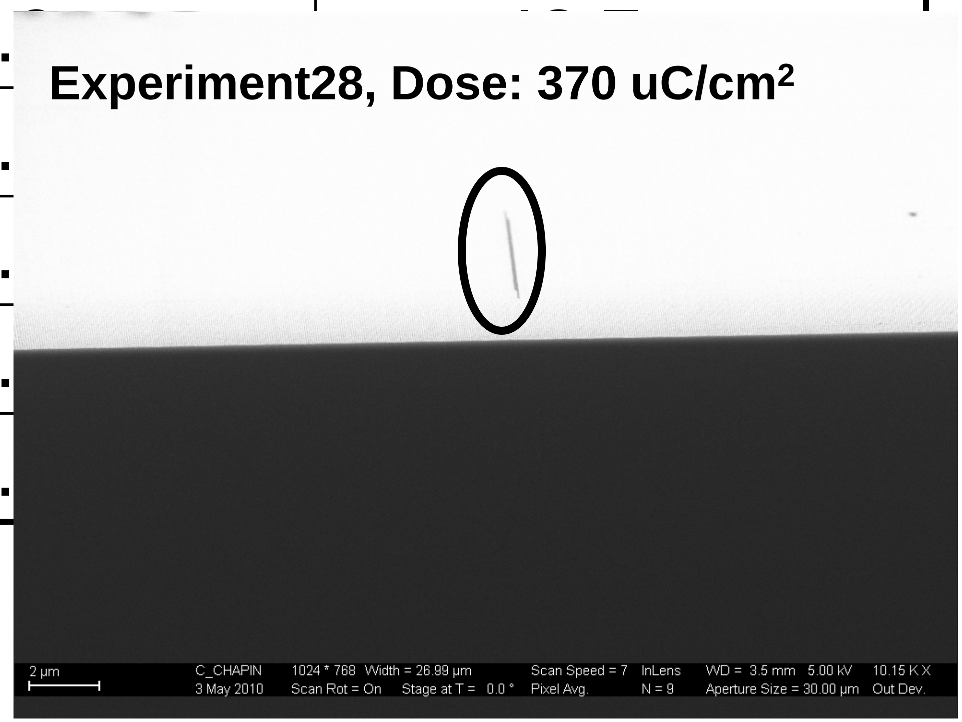




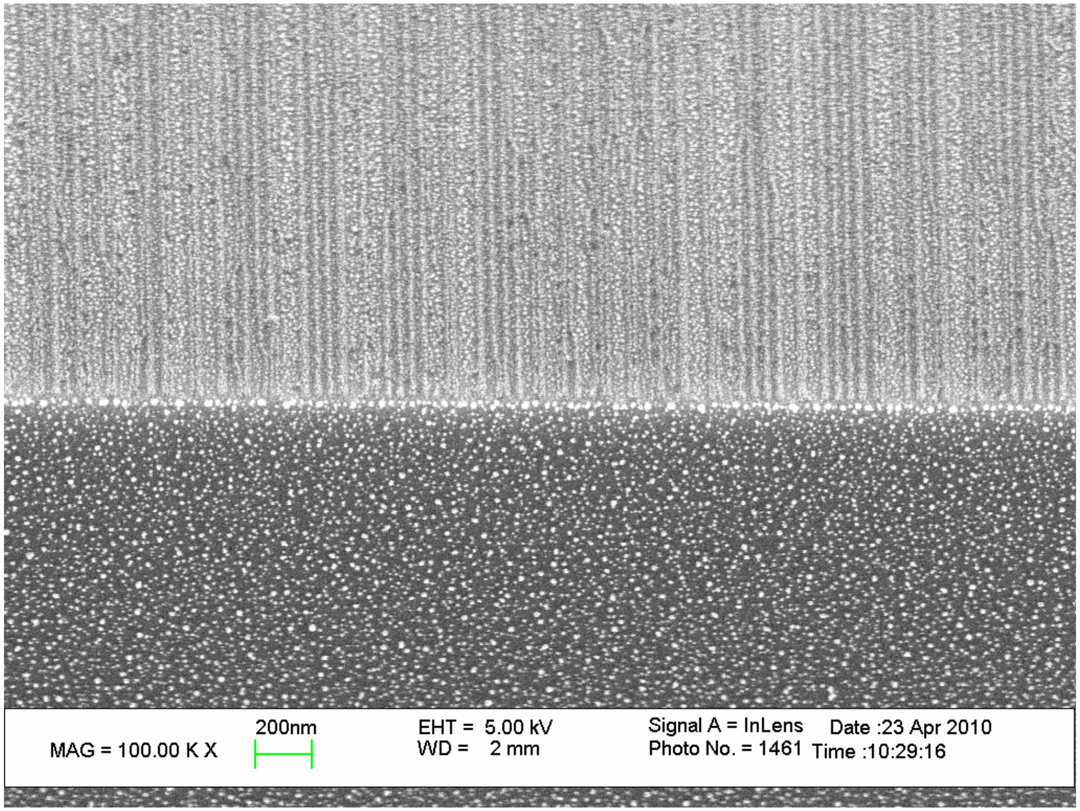


Adhesion Failure Driven by Resist Thickness

	Nanospec Measurement	**Zeiss Measurement**
Experiment19	59.9nm	36.7nm
Experiment20	59.[illegible]	[illegible]
Experiment22	35.[illegible]	[illegible]
Experiment23	35.[illegible]	[illegible]
Experiment24	41.[illegible]	[illegible]
Experiment28	21.[illegible]	[illegible]

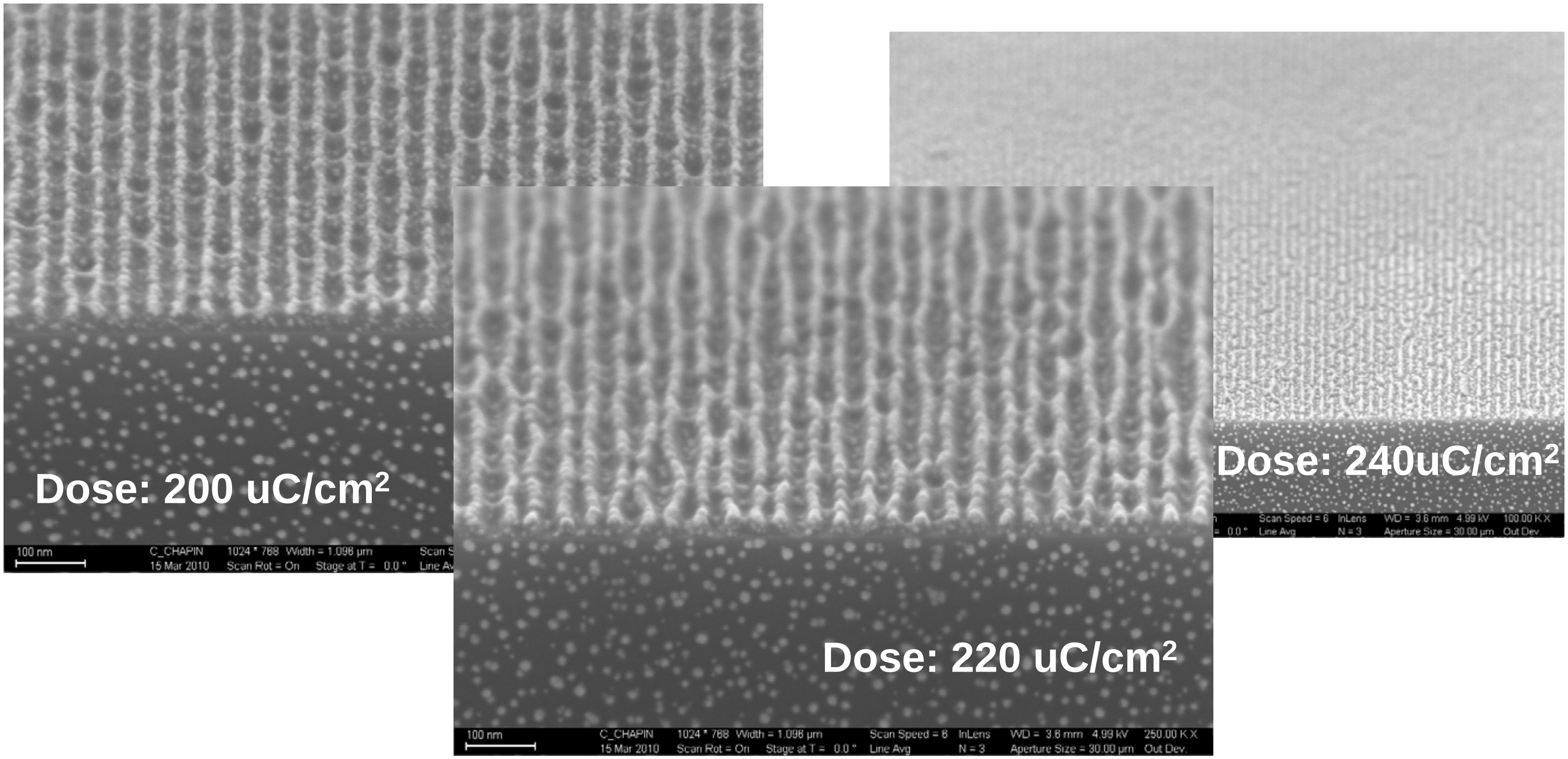


20nm L/S with 0°C Develop



- Same as original experiments without cold development
  - Breaking up where there are also stringers

20nm Lines:
Tool or Resist



- Sample run at Brookhaven National Lab where they have a 6300

Summary

- Resist thickness effects sensitivity of ZEP520
- ZEP520's properties change with different development conditions
  - Cold develop improves contrast and resolution, decreases sensitivity
- By developing ZEP520 at 0°C for 30 seconds, we're able to achieve a 30nm line and space pattern
  - Still, need to solve adhesion failure
  - 30nm possibly resolution limit of dense features exposed in ZEP520, further work needed on this topic

Work Cited

1. X. Yang, S. Xiao, W. Wu, Y. Xu, K. Mountfield, R. Rottmayer, *Journal of Vacuum Science and Technology*, vol. 25, no. 6 (2007).
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3. S. Long, Z Li, X. Zhao, B. Chen, M. Liu, *Advanced Microlithography Technologies*, vol. 5645, 2010.
4. K. Gonsalves, L. Merhari, H. Wu, Y. Hu, *Advanced Materials*, vol. 13, no. 10, 2001.
5. D. M. Tanenbaum, M. J. Rooks, K. Y. Lee, W. S. Huang, T. H. P. Chang, *Journal of Vacuum Science and Technology,* vol. 14, no. 6, 1996.

Questions?