ZEP EXPOSURE & DEVELOPMENT RESULTS

This document provides exposure and development conditions for patterning the ZEP-520A electron beam resist. Please refer to the Raith 150/150^{TWO} SOPs and the Ladd SK-12D Cold Plate SOP prior to reading this document.

Resist Thickness: 60 nm
Voltage: Various ~ 1, 3, 10, 30 keV
Aperture: 10 µm
Clearance doses: Depends on structure, conditions, etc – given below.
Development: (a) 30 sec in ZED-N50 + 20 sec rinse in MIBK (Both at 22°C room temperature)
(b) 30 sec in ZED-N50 + 20 sec rinse in MIBK (Both at -15°C on a cold plate)

Table 1 Area doses required to pattern 100nm line/space periodic patterns

Voltage (keV)	Dose @ 22°C development (µC/cm^2)	Dose @ -15°C development (µC/cm^2)
1	2.5	8.4
3	7	20
10	24	100
30	62	240

Table 2 Line doses required to pattern 100nm pitch gratings

Voltage (keV)	Dose @ 22°C development (pC/cm)	Dose @ -15°C development (pC/cm)
1	13	-
3	27	75
10	74	250
30	175	-

NOTES:

- The doses given in tables 1 and 2 are lower bound (minimum) values.
- The area doses required to pattern large boxes is approx. 20% less than what is required to pattern 1:1 line/space patterns (refer to table 1).
- The line dose range is approx. 2x the stated minimum values (table 2). For example, using 1 keV, 22°C development, the dose window can safely be assumed as approx. 13 – 26 pC/cm.
- For curved and dot doses, a table comparing 22°C and -15°C development is unavailable.
    - For curved doses, use the same values as area doses.
    - For dot doses, use 1 – 20 fC (0.001 – 0.02 pC) as starting doses for 1 – 30 keV voltages, when using 22°C development. As an example, to get a 150 nm dot using 3 keV and 22°C development, a dot dose of 3.6 fC was required. Some additional data is given on page 3.

ZEP & COLD DEVELOPMENT:

- The benefits of cold development include (i) improved resolution, and (ii) improved line edge roughness (LER) at the cost of (a) reduced sensitivity, and (b) greater process setup.
- For the given exposure conditions, sub-20 nm features can only be attained using cold development. Comparing Fig. 1 and Fig. 2, the individual line widths are approx. 2x less (32nm vs. 16nm).
- Cold development also allows denser patterns to be fabricated. As an example, 60nm pitch gratings could easily be fabricated as shown in Fig. 2 with improved LER. The best grating pitch achieved by room temperature development was 70nm (not shown).

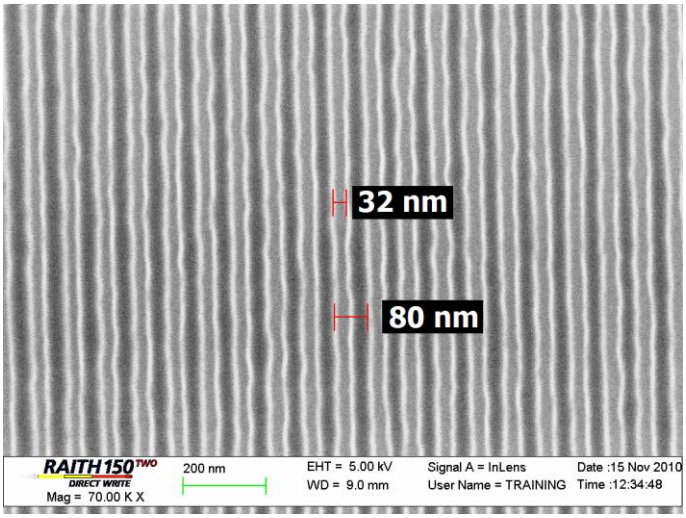

Fig. 1. 32nm gaps in 80nm pitch gratings using 10 keV, 100 pC/cm, and 22°C development process (a)

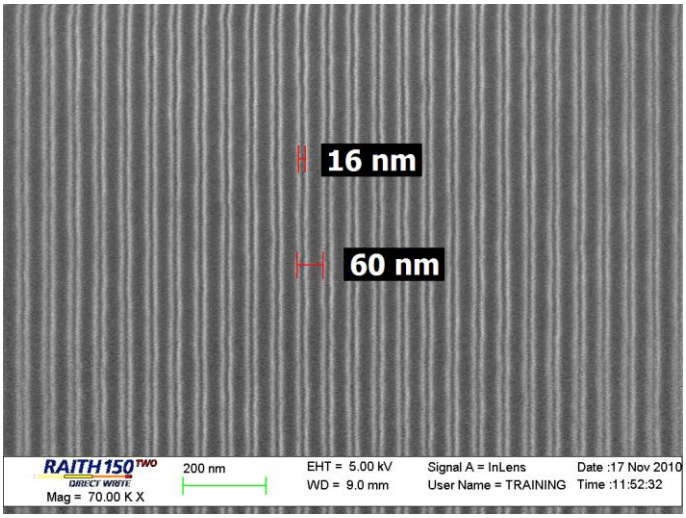

Fig. 2. 16nm gaps in 60nm pitch gratings using 10 keV, 160 pC/cm, and -15°C cold development process (b)

ZEP vs. PMMA?

- **(+)** The sensitivity of ZEP-520 was found to be 5x higher than PMMA. To pattern sub-20 nm features in PMMA using cold development, a line dose of 800 pC/cm was used compared to just 160 pC/cm for ZEP-520 as shown in Fig. 2.
- **(~)** The resolution of ZEP-520 is equivalent to that of PMMA for room temperature and cold development conditions.
- **(-)** ZEP has greater line edge roughness (LER) compared to PMMA. Note that (i) this should not worry you for large structures or if LER is not important for your process, and (ii) LER improves by using cold development.
- **(+)** ZEP has better etch durability compared to PMMA. The etch selectivity of Si/ZEP is approx. 3x higher compared to Si/PMMA.
- **(+)** ZEP is more resilient than PMMA e.g., ZEP can withstand supercritical drying processes whereas PMMA cannot.

ADDITIONAL IMAGES:

The figures below demonstrate that ZEP can be used for EBL patterning a variety of complex nanostructures.

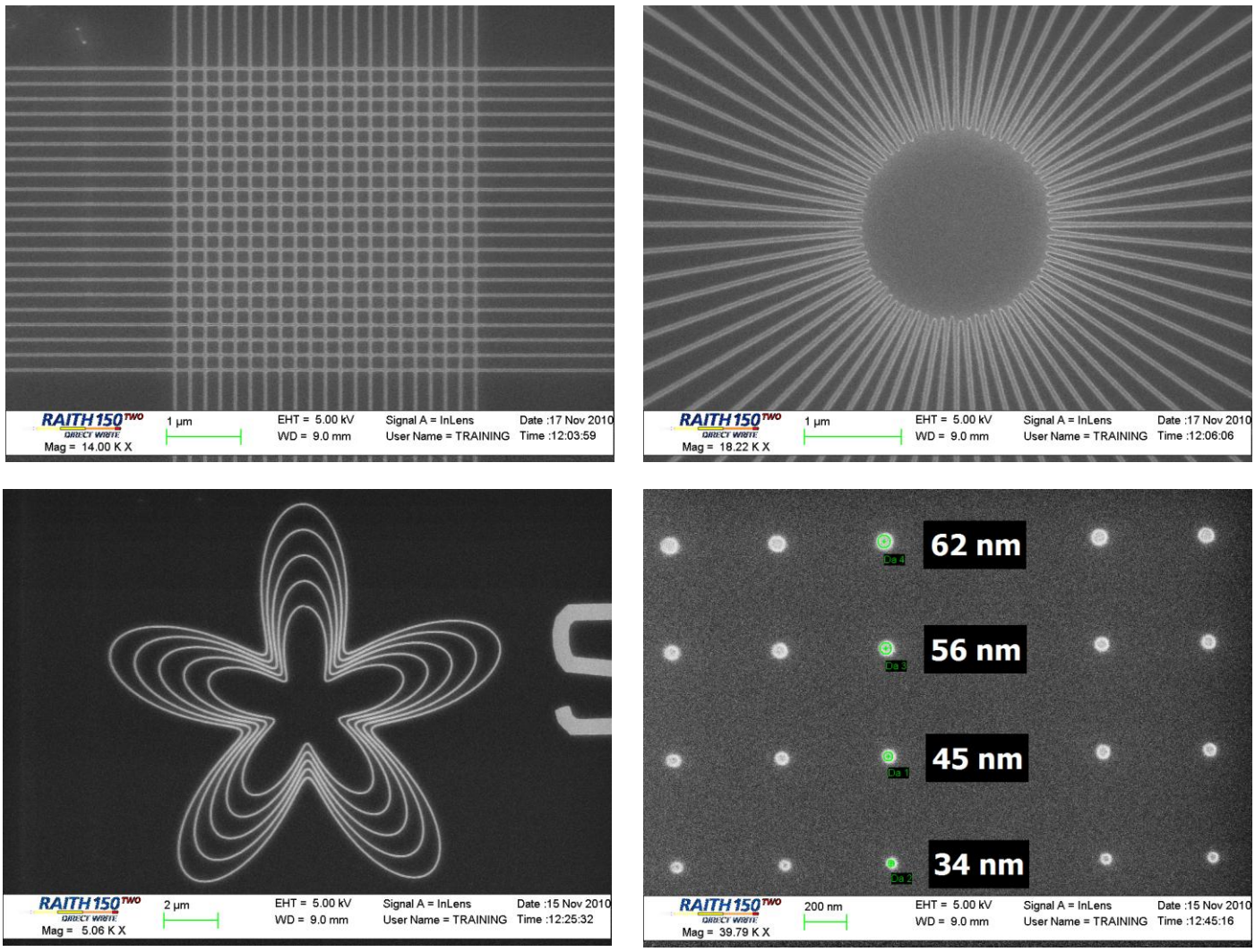

Fig. 3. Various nanoscale patterns fabricated using ZEP-520A resist

Note: Conditions for dots patterned in Fig. 3 – 10 keV, 60 nm thick ZEP, and 22°C development. Dot doses of 2, 3, 4, and 5 fC (0.002 – 0.005 pC) yielded 34, 45, 56, and 62 nm dots.

If you have any questions regarding the above, please contact Mohammad Ali Mohammad (ebl.nanofab@ualberta.ca). If you require training on the Raith systems, please contact the qualified trainers mentioned in the Raith SOP. Should none of the above contacts be available, please contact any staff member for assistance.