

I. Project Objectives

The objective of this project was to achieve the formation of lamellar (line/space) structures using Polystyrene-block-Poly Methyl Methacrylate (PS-b-PMMA) Block Copolymers (BCPs). The process flow was based on research published by S.J. Jeong [2], and was carried out using the combined resources of the SMFL and the Smith Laboratory.

II. Motivation

As technology nodes continue to shrink, the challenges of cost effectively integrating patterning solutions are rapidly mounting. DSA is a method potentially capable of achieving low cost sub-lithographic patterning, and the establishment of a DSA process at RIT could enable further research and academic teaching opportunities.

III. Process Flow

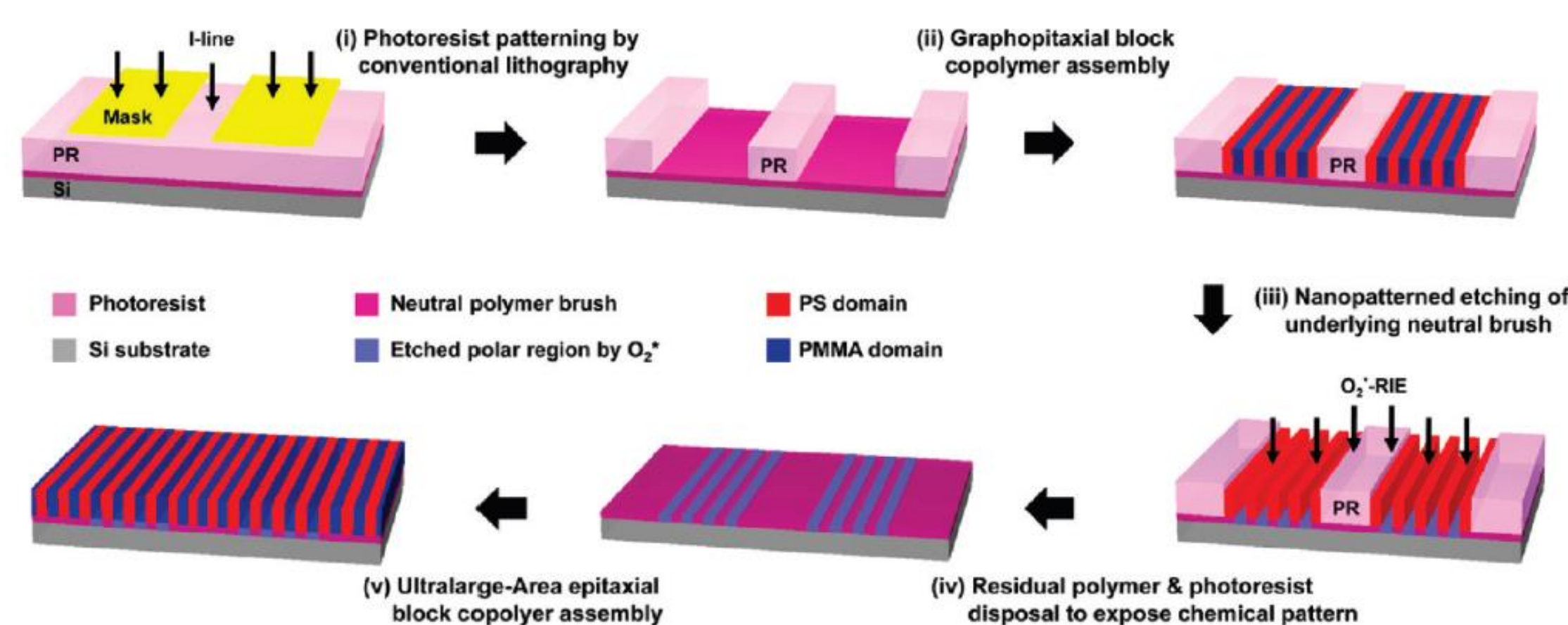
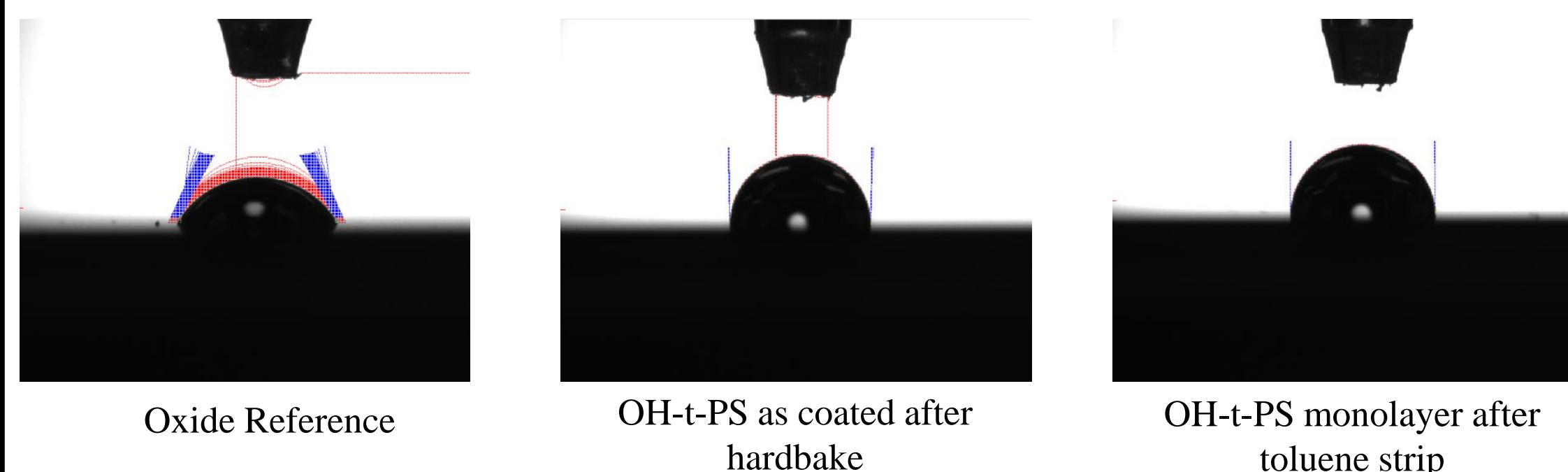


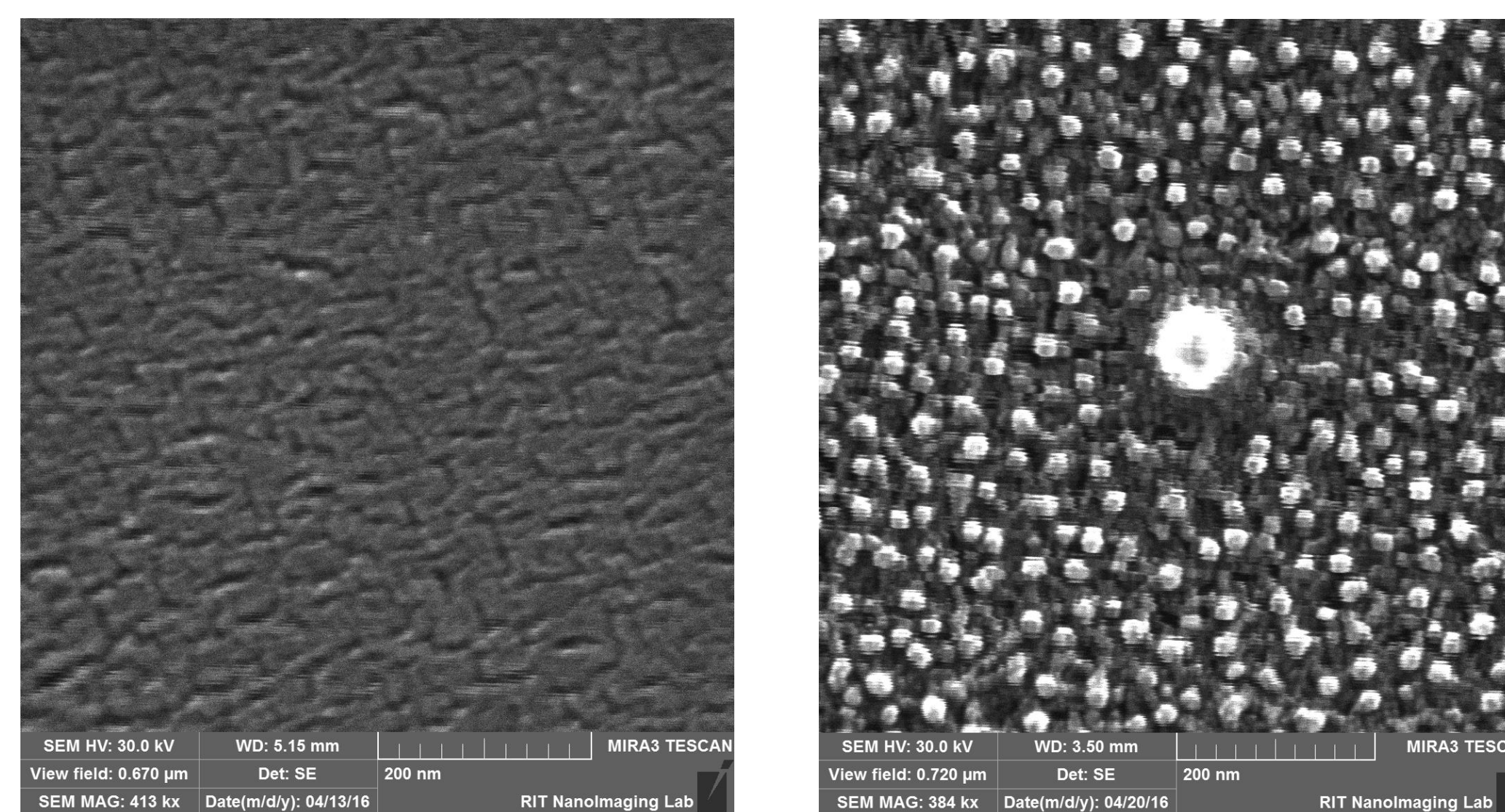
Figure 1: High-level DSA process overview [1].

Silicon wafers (n-type) with 1000Å of thermally grown oxide were used as the starting substrates. A surface brush material composed of OH-t-PS was applied and chemically bonded via an anneal at 120°C for 24 hours. nLOF-2020 photoresist was then diluted to approximately 1:1 nLOF:PGMEA and spincoated at 3000RPM to a thickness of 130nm. After lithographic patterning, the BCP (2% PS-b-PMMA in Toluene) was coated to a thickness of 45nm at 3000rpm for 2 minutes. Solvent Vapor Annealing (SVA) was carried out in toluene for 10 minutes. After the SVA, an O₂ RIE was done in the Drytek Quad for 30 seconds at 50W with 70mT pressure and 40sccm O₂ gas flow. PS domains remain while the PMMA is ashed away. Samples were then taken to the RIT Nano-Imaging Lab and analyzed via field emission SEM. All film thicknesses were measured via ellipsometry and surface brush removal was verified via contact angle measurement.

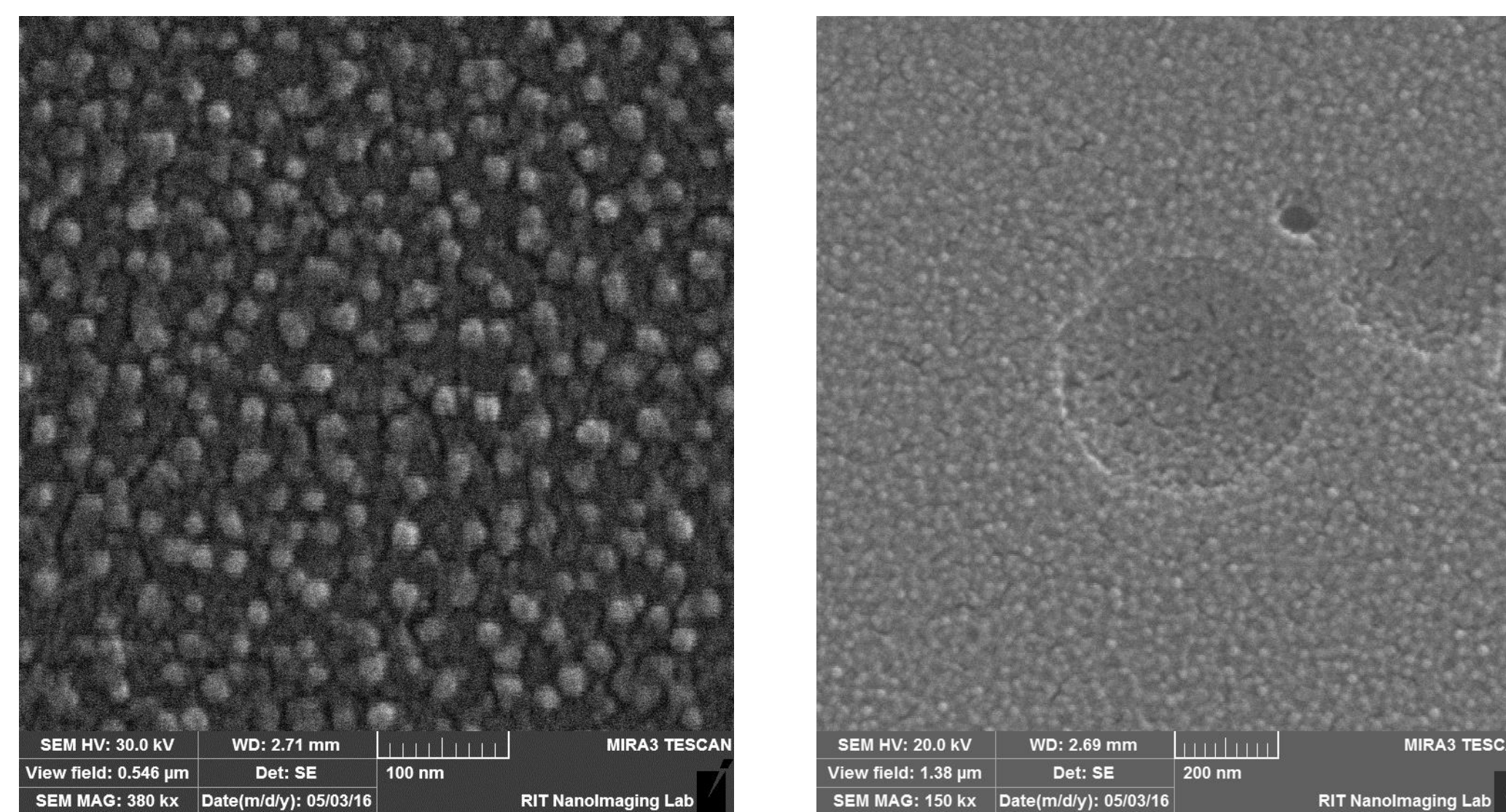
IV. Experimental Results



Contact angle characterization of the surface brush process verified the presence of a polystyrene monolayer after solvent strip. The silicon dioxide demonstrates hydrophobic behavior with no measurable OH-t-PS remaining on the surface.



The left image shows etch testing on a non-assembled (non-annealed) unpatterned substrate. The right image is an unpatterned sample which has been annealed and undergone directed self-assembly. The non-annealed substrate shows no pattern as expected, and the annealed substrate shows the formation of Polystyrene contact pillars.



Evaluation of final DSA pattern in Polystyrene demonstrates contact pillar type morphology in a dense line/space grating (left) and hole (right.) Lithographic direction did not have a significant effect on the DSA structures formed.

IV. Results (Cont.)

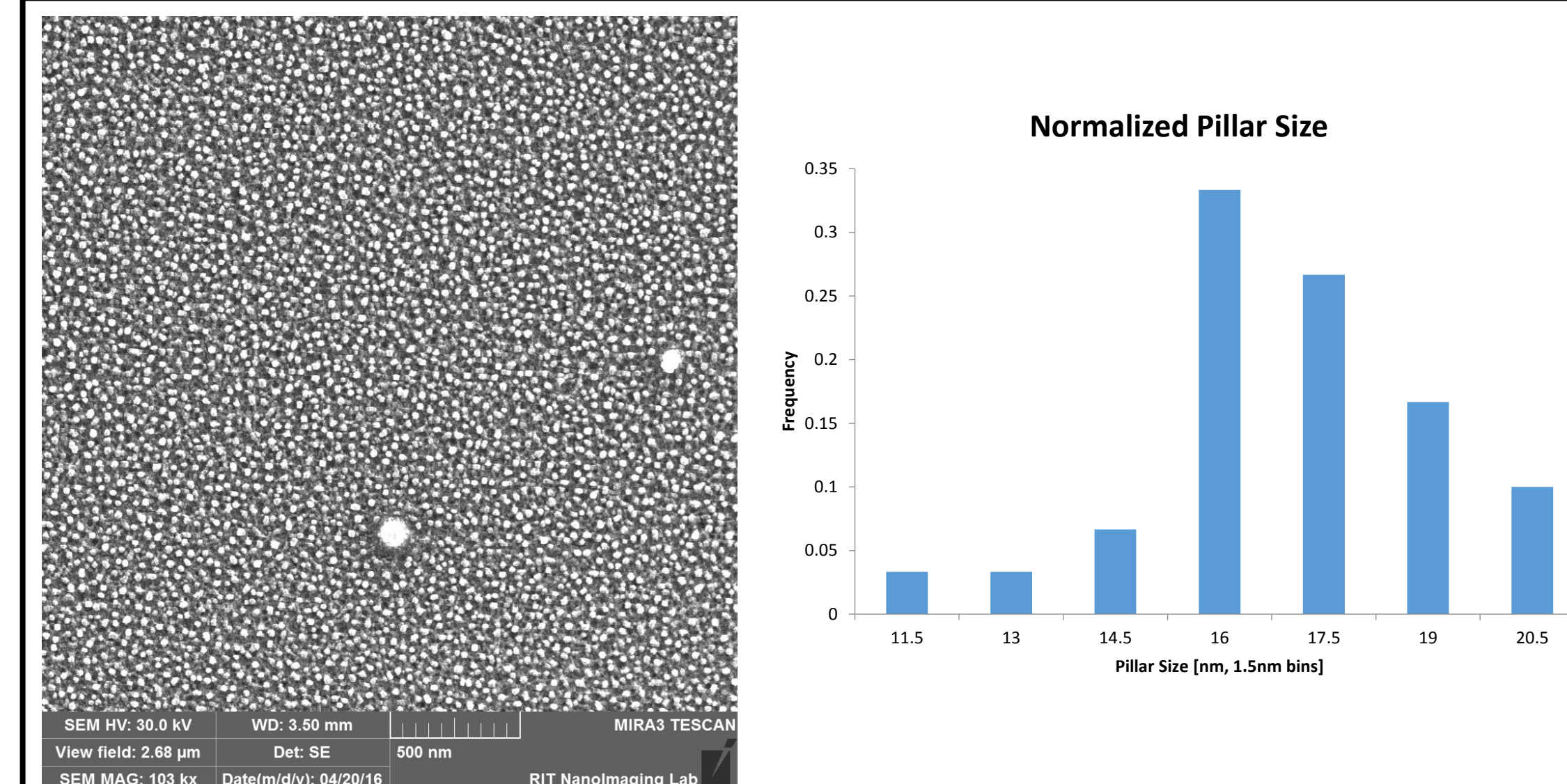


Image analysis software was used to analyze the size of the Polystyrene pillars formed during DSA. A sample of 50 random pillars yielded a mean size of 16.8nm, with a standard deviation of 2.3nm. Despite the lack of the anticipated lamellar morphology, this process yields dense contact pillars with relatively uniform critical dimensions.

V. Conclusions

The anticipated lamellar morphology was not observed in this project. A pattern of dense contact pillars of 16.8nm in size was achieved. To best utilize this process, a tone reversal process should be used to form contact holes. Future work for this project could include matching the resist/BCP film heights to assist in BCP formation, and the use of a randomly polymerized PS undercoat in place of the surface brush. Smaller trench CDs could also be explored to attempt to force the DSA pattern into a lamellar morphology. Thermal annealing could also be refined and explored as an alternative to the SVA used in this project.

VI. References

- [1] S. Jeong and S. Kim, "Ultralarge-area block copolymer lithography via soft graphoepitaxy", *Journal of Materials Chemistry*, vol. 21, no. 16, p. 5856, 2011.
- [2] K. Koo, H. Ahn, S. Kim, D. Ryu and T. Russell, "Directed self-assembly of block copolymers in the extreme: guiding microdomains from the small to the large", *Soft Matter*, vol. 9, no. 38, p. 9059, 2013.
- [3] S. Jeong, H. Moon, B. Kim, J. Kim, J. Yu, S. Lee, M. Lee, H. Choi and S. Kim, "Ultralarge-Area Block Copolymer Lithography Enabled by Disposable Photoresist Prepatterning", *ACS Nano*, vol. 4, no. 9, pp. 5181-5186, 2010.

Acknowledgements

- SMFL Staff
- Dr. Robert Pearson and Dr. Dale Ewbank (Project Advisors)
- Dr. Thomas Smith (Research Advisor)
- Dr. Richard Hailstone (SEM Imaging)
- Dr. Surendra Gupta (AFM Imaging)

