Nanometer-Scale Area-Selective Formation of Polymer Brushes

CNF Project Number: 1757-09

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Primary CNF Tools Used: E-beam resist spinners, JEOL 9500, FilMetrics F50-EXR, Oxford 81 etcher, Zeiss Ultra SEM, optical microscope

Abstract:

The topological control of polymer brushes can be realized via surface-initiated polymerization on a pattern fabricated by electron-beam (e-beam) lithography, which is known for its fine resolution and precision. Patterned polymer brushes were produced on silicon wafers by selective deposition of initiator, using patterned e-beam resists as the masks. As a result, cone-like polymer brushes with a height of ~ 60 nm and diameter of ~ 60 nm were formed in the desired pattern. This platform has several potential uses, including cytoskeleton mimicry and molecular recognition.

Summary of Research:

Introduction. Polymer brushes have a unique molecular structure with one end of the polymer chain covalently bonded to a substrate, such as a silicon wafer. Fabricating these brushes has been one of the main areas of focus in polymer science in recent decades and has demonstrated interesting applications in many fields [1]. The precise, nanometer-scale patterning of e-beam lithography can be incorporated with surface-initiated polymerization to provide a novel pathway in the area-selective placement of polymer brushes on hard substrates. This results in surfaces with anisotropic properties, unique chemical functionality, and responsive behavior under different stimulations.

Fabrication. The polymer brushes were patterned on a silicon wafer by depositing polymerization initiators selectively on desired areas. This was accomplished by patterning the e-beam resist (~150nm) through JEOL 9500 and using it as the mask for deposition. Before depositing the initiator, the surface of the substrate was etched ~ 10 nm to remove residual debris. The deposition of a silane initiator was carried out in the vapor phase, followed by the removal of the resist. Subsequently, surface-initiated ring-opening polymerization was carried out under vacuum and elevated temperature [2]. A schematic illustration of the fabrication process is shown in Figure 1.

Characterization and Results. The thickness of the e-beam resist was found using FilMetrics F50-EXR after spin-coating. After the exposure and developing process, the e-beam resist was analyzed by Zeiss Ultra SEM (Figure 2). The patterned polymer brushes were characterized using atomic force microscopy (AFM) in Cornell Center for Materials Research (Figure 3) for height measurement, and Zeiss Ultra scanning electron microscope (SEM) for topological analysis (Figure 4).

Conclusions. We demonstrated that e-beam lithography can be used to precisely control the spatial arrangement of polymer brushes. In the near future, we plan to explore the use of these surfaces for biological applications, such as cell membrane support and molecular recognition.

References:

[1] Chen, W.-L.; Cordero, R.; Tran, H.; Ober, C. K. 50th Anniversary Perspective: Polymer Brushes: Novel Surfaces for Future Materials. Macromolecules 2017, 50 (11), 4089-4113.

[2] Wang, Y.; Chang, Y. C. Preparation of Unidirectional End-Grafted α-Helical Polypeptides by Solvent Quenching. J. Am. Chem. Soc. 2003, 125 (21), 6376-6377.

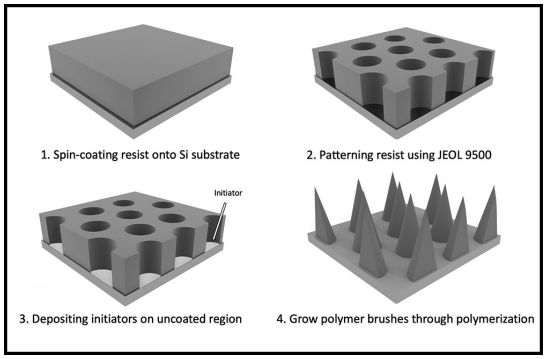

Figure 1: Schematic illustration of the fabrication process.

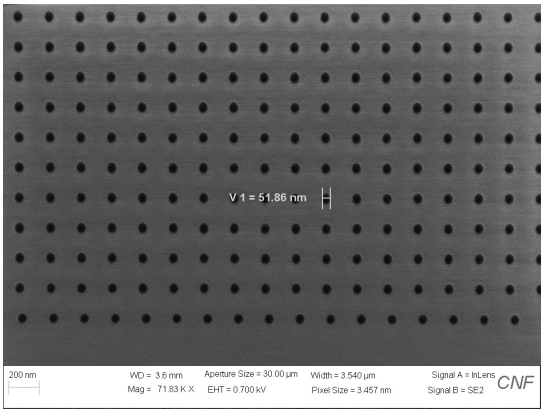

Figure 2: The e-beam pattern after the exposure and developing processes.

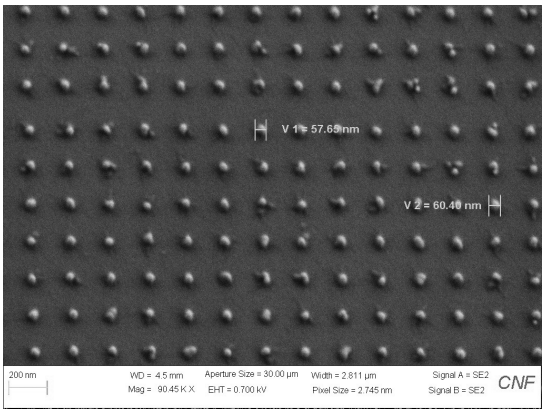

Figure 3: An SEM image of the polymer brushes. The diameter is around 60 nm.

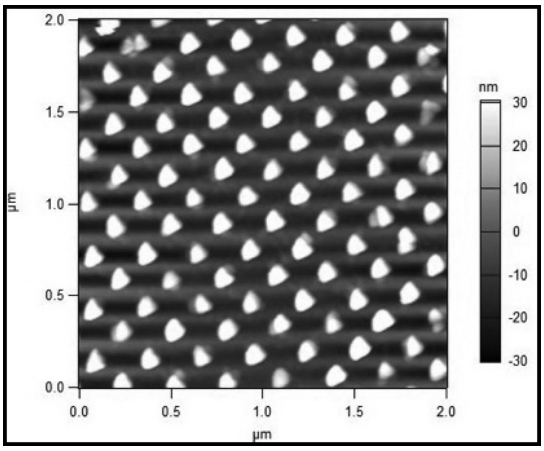

Figure 4: An AFM image of the polymer brushes. The height is around 60 nm.