Aberration-Corrected Electron-Beam Lithography

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Electron-beam lithography (EBL) at the sub-10 nm scale is of critical importance for nanoscience, nanotechnology, and low-volume manufacturing. One approach for improving EBL resolution is by reducing the electron beam diameter. This may be accomplished by using an aberration-corrected scanning transmission electron microscope (STEM) as the exposure tool. We have previously reported that an EBL exposure with 1 Angstrom probe diameter provided isolated lithographic feature sizes as small as 2 nm and 10 nm periodic structures in hydrogen silsesquioxane resist.[1] These results are a significant improvement upon exposures of the same resist compared with non-aberration-corrected EBL systems.[2, 3] Furthermore, the resolution limit for the fabrication of isolated structures was attributed to the spot size and resist stability, while the resolution limit of dense structures was attributed to volume plasmon generation.[4] Here we report further development of this aberration-corrected EBL by installing a pattern generator (Nanometer Pattern Generation System, JC Nabity Lithography Systems) to the aberration-corrected STEM. We believe this to be the first aberration-corrected EBL system, operating at 200 keV.

Figure 1 shows the initial results from our aberration-corrected EBL system. The resist used was 60-nm-thick poly(methyl methacrylate) (PMMA) coated on a 10-nm-thick SiN_x membrane substrate. The patterned PMMA was imaged with the same STEM. Figure 1A shows the overview of the pattern written in a single write field. We fabricated multiple hole arrays with increasing dose (Fig.1A, top), gratings with increasing dose (Fig.1A, bottom), and the initials of our laboratory (Fig.1A, bottom right). All patterns were written with a single pass exposure. The PMMA was developed at 0°C for 30s in 3:1 IPA:MIBK solution. Figure 1B shows the acronym of our nanocenter: 'CFN' (~ 25 nm line width) demonstrating the arbitrary patterning capability at high resolution. Figure 1C shows one hole array with small dose, with 8 ± 2 nm diameter dots. Furthermore, we will show pattern transfer in this system using lift off and reactive ion etching, and we will investigate the possibility of sub-nm alignment accuracy in this EBL system.

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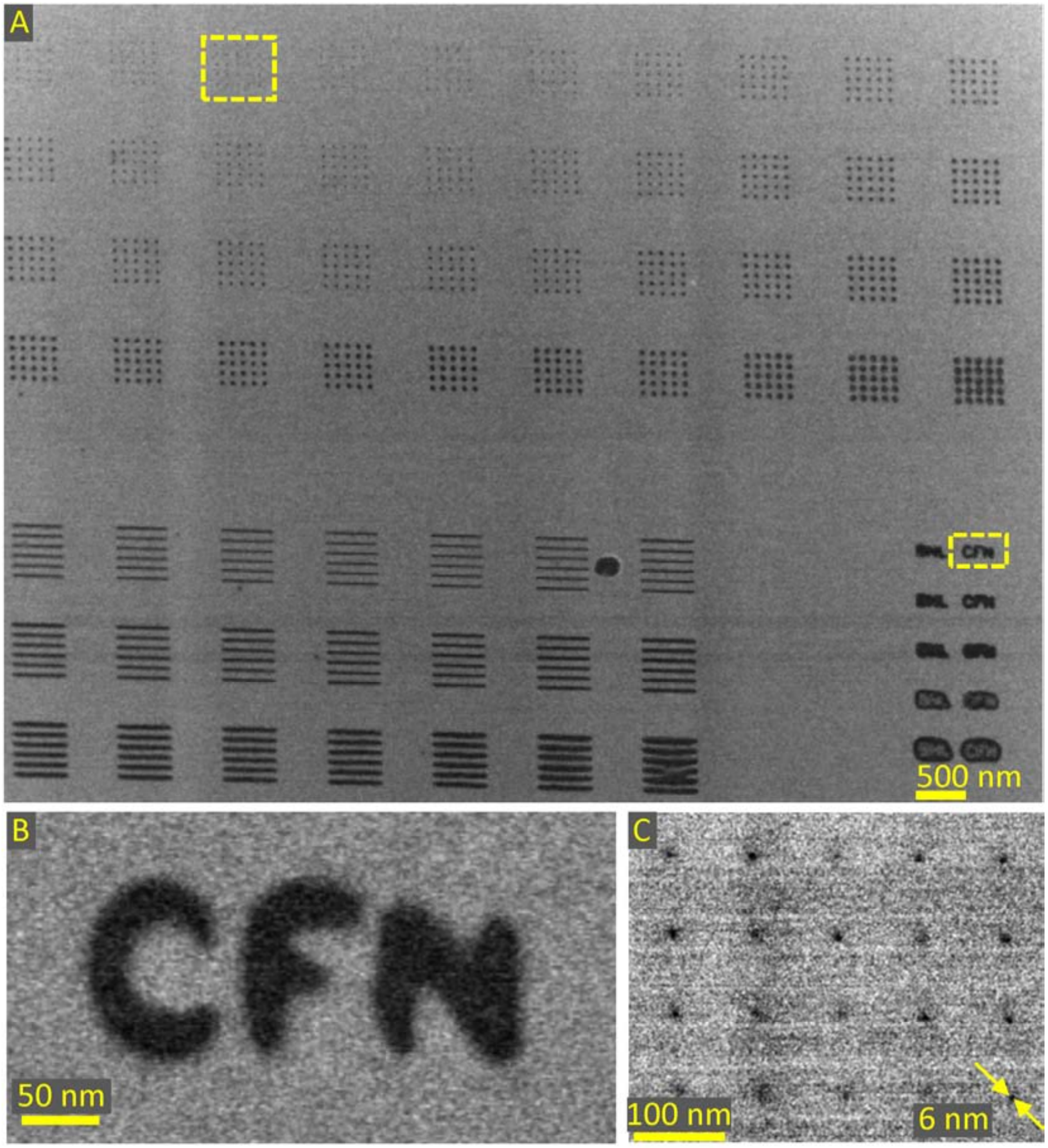

Figure 1. Scanning transmission electron micrographs of poly(methyl methacrylate) (PMMA) resist patterned with an aberration-corrected scanning transmission electron microscope at 200 keV using a pattern generator. The PMMA was 60 nm thick and the substrate was 10-nm-thick SiN_x membrane. **A.** Overview of the pattern written in a single write field and single-pass lines (1 nm step size). The yellow dashed frames indicate representative areas of the pattern to be shown in B and C. **B.** The letters 'CFN' patterned in PMMA, showing the arbitrary pattern capability of our lithographic system. **C.** Hole array of 100 nm pitch fabricated in PMMA with 8 ± 2 nm feature size. The dot dose was 12 fC/dot.