Patterning materials efficiently at the smallest length scales is a longstanding challenge in nanotechnology. Electron-beam lithography (EBL) is the primary method for patterning arbitrary features, but EBL has not reliably provided sub-4 nanometer patterns. The few competing techniques that have achieved this resolution are orders of magnitude slower than EBL. In this work, we employed an aberration-corrected scanning transmission electron microscope for lithography to achieve unprecedented resolution with arbitrary designs.

This work demonstrates aberration-corrected EBL producing 1.7 ± 0.5 nm feature size in negative-tone poly(methyl methacrylate) (PMMA) resist, 2.5 ± 0.7 nm feature size in positive-tone PMMA resist, and 1.5 ± 0.8 nm feature size in hydrogen silsesquioxane resist. We also demonstrate pattern transfer from the resist to semiconductor (silicon, zinc oxide) and metallic (gold) materials by lift off, sequential synthesis infiltration, and reactive ion etching, all at the sub-5 nanometer scale. In addition, we measured line-edge roughness of patterned Si atom-by-atom, with an unbiased line-edge roughness of 1 nm (3-sigma). We believe aberration-corrected EBL will open up the sub-5-nm design space.