Atomic Precision Lithography on Si

J.N. Randall[a], J.W. Lyding[b], S. Schmucker[b], J.R. Von Ehr[a], J. Ballard[a], R.Saini[a]
a) Zyvex Labs, Richardson Texas .b) University of Illinois, Urbana Champaign

Lithographic precision is at least as important as resolution. For decades, the semiconductor industry has been able to work with +/- 5% precision. However, higher precision is desirable as downscaling approachs the fundamental quantization of matter, enabling new applications such as Micro/Nano Electro Mechanical Systems (MEMS/NEMS), optical elements, and bio-interface applications.

Lyding[1] and others have demonstrated that a Scanning Tunneling Microscope (STM) can be used to remove H atoms from a Si (100) 2x1 H-passivated surface in UHV through an electron stimulated desorption process. This can be considered e-beam lithography with a thin, self-developing resist. Patterned hydrogen layers do not make a robust etch mask, but the depassivated areas are highly reactive due to unsatisfied covalent bonds, and have been used for selective deposition of metals[2], oxides[2], semiconductors[3], and dopants[4].

Depassivation lithography can remove single H atoms[1], suggesting that atomic precision patterning may be possible. Figure 1 shows a near perfect pattern. Overcoming a “few” engineering challenges is all that is required to make routine, atomic precision patterning possible.

The paper will review some of the fundamentals of H depassivation lithography and demonstrate how some concepts such as variable spot e-beam lithography, quantum lithography[5], and spatial phase lock[6] can be employed to automate an atomic precision lithography process. We show progress on improving tip technology, image drift correction, automation of the lithography process, and improving the patterning throughput. Unlike other scanning probe patterning efforts that manipulate atoms and molecules on surfaces, this process is essentially e-beam lithography and does have significant scale-up potential. This effort is part of DARPA’s Tip Based Nanofabrication (TBN) program which has aggressive metrics with respect to scaling up the throughput of the technology.

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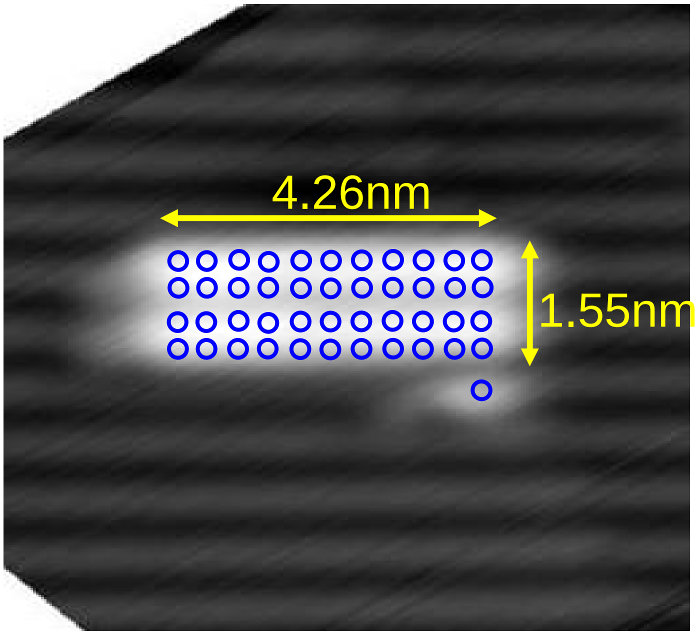

Figure 1. A rectangle 1.55 x 4.26 nm which consists of 44 H atoms removed from a Si (100) 2x1 H-passivated surface by an STM, The blue circles indicate where the H atoms have been removed. Only a single unwanted depassivation H in the lower right restricts this from being an example of perfect patterning. The image was taken by an STM at a bias that does not remove H.