Atom-based Pitch and Length Standards

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Dimensional metrology at the atomic scale has a critical role in providing the necessary accuracy and reliability required for future nano manufacturing applications. The main focus of this work is developing methods to fabricate structures on the near atomic scale whose dimensions can be measured and traced directly to the intrinsic crystal lattice. These samples are intended to be dimensionally stable and allow transfer to other measurement tools which can measure the artifacts with dimensions known on the sub-nanometer scale. This scanning tunneling microscope (STM)-based technique relies on atomically sharp tips to provide robust imaging, and atomically-resolved patterns which can be transferred into the silicon substrates using appropriate etching methods. These atomically precise patterns then serve as stable, atom-based standards.

The modification of silicon surfaces by patterning the silicon substrates using an STM probe in a UHV environment is central to the fabrication of pitch standard artifacts. Fiducial marks that are pre-etched on the silicon (100) samples serve as micro-scale coordinates to facilitate locating the atomic scale features at the macroscopic scale. The fiducial marks have also been found to play a significant role in controlling the silicon step-terrace dynamics during annealing thereby creating large atomically flat terraces in a controlled manner. The silicon substrates are hydrogen-passivated after an extensive UHV annealing process, followed by selective depassivation lithography using an STM to create nanopatterns. The patterns are then made robust by a selective oxidation/ chemical modification with a subsequent RIE etch process. One of the main challenges addressed is obtaining sufficient etch selectivity for patterns at the near atomic scale. This presentation will also evaluate the various methods used to test and optimize the selectivity and resistance to etching. Results will also include SiO2 masks formed by patterned oxidation followed by metal oxides masks produced by the chemical selectivity of atomic layer deposition (ALD). Following selective ALD these samples are then etched using a reactive ion etching process to further enhance their aspect ratios. Silicon atom-based artifacts created by these processes are preserved over time in a moderately controlled environment and to be used as atomic scale dimensional standards.