Nanoscale Deposition and Etching of Silicon Quantum Dots Using Field-Assisted AFM-Based CVD

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Electric-field assisted decomposition of gas molecules near a conducting AFM tip can be used to directly deposit, etch and pattern nanometer-scale silicon structures. We used $SiCl_4$ to deposit silicon on a poorly conducting silicon substrate and SF_6 to etch silicon at room temperature and one atmosphere. Deposition required around + 50 MV/cm (~ +30 V) while etching could be achieved at lower fields around - 10 MV/cm (~ -10 V) with the voltage polarity as applied to the tip. Deposition and etching from gas phase is relatively a clean process since the byproducts are in gas phase. It is also potentially very fast since gas molecules at 1 atmosphere have around 60 nm mean-free-path and are readily available on demand. Owing to relatively large curvature of our current AFM tip apex ~ 40 nm, the smallest feature size we could pattern was around 100 nm. We discuss kinetics of formation of these dots and propose a reaction mechanism that is being evaluated to improve the spatial resolution of this unique technique. We also discuss the role of thermal decomposition that can deteriorate the spatial resolution of tip-based CVD processing. To avoid thermal contribution and spreading, the tip voltage should be pulsed. We are also in the process of adding microwave excitation to the tip to reduce I^2R heating.

The AFM-based CVD technique is being extended to include electrodes directly on the probe to eliminate any need for conducting substrate. With excitation completely contained in the tip, the AFM-based nanofabrication will become versatile and can be used as a 3-D mask-less nanofabrication on any material from polymers to diamond to clays. To demonstrate the feasibility of this approach, we have developed micro-plasma sources that are being scaled down to nano-scale for direct write and etching.

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