Gas Dosing for Tip Based Nano-Fabrication Processes

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Tip based nanofabrication (TBN) processes promise unprecedented degrees of control and precision for the manufacture of nanostructured materials and devices. These processes rely on AFM or STM tips to create localized electric fields, electron beams, and other catalyzing conditions to control and detect the position, size, dimension and orientation of nanostructures. Tip based approaches have deposited metals[1], oxides[2], and organic molecules[3] to name a few. Typically, a gas phase precursor is required to provide the material for the structure. The TBN conditions for gas dosing are unique compared to other fabrication processes, e.g. CVD. The manufacture of precision nanostructures requires a contamination free environment, and hence ultra-high vacuum conditions must be maintained in the chamber at large. Substrate temperatures must be moderate to limit surface diffusion that could dismantle a nanostructure, which affects sticking coefficients and desorption kinetics. TBN may build up a nanostructure through a series of steps, monolayer by monolayer, requiring multiple gas dose pulses. To be practical TBN must be high rate requiring gas dosing at a high frequency. To achieve rapid deposition rates while limiting the burden placed on the vacuum pump the gas dose must be focused and restricted to the intended fabrication area.

Continuum gas dynamics and Direct Simulation Monte Carlo (DSMC) calculations were used to show that gas dosing takes the form of a diverging jet in free molecular flow under TBN conditions. The source pressure, doser design and separation distance are shown to affect the flux distribution at the substrate, molecular impact energy and dynamic response of the system. Modeling of the adsorption and decomposition processes of silicon species on silicon substrates was used for determining the total gas dose required to deposit a monolayer. The calculated results are compared to experimental measurements of gas doser deposits. A proposed gas doser design and predicted performance will be reported.

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