

Automated and Robust Nano-Assembly with Atomic Force Microscopes

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Abstract:

Atomic force microscopes (AFM) can be used to both image and modify samples at molecular or even atomic resolution, in an ambient environment with little to no sample preparation. AFM based nanomanipulation and nanoassembly compares favorably with other techniques such as electron-beam lithography in cost, repeatability, accuracy, and resolution. However, fundamental challenges exist in such AFM based nanomanipulation, precluding it from becoming a full-scale manufacturing technology, a) lack of real-time visual feedback ; b) spatial uncertainties induced by hysteresis, creep and thermal drift; c) unreliable transportation of samples. The goal of this collaborative research is thus to develop an AFM based cyber-physical system (CPS) that can enable automated, robust and efficient assembly of nanoscale components such as nanoparticles, carbon nanotubes, nanowires and DNAs into nanodevices. The proposed approach is based on the premise that automated, robust and efficient nanoassembly can be achieved through tip based pushing in an AFM with intermittent local scanning of nanoscale components. We have developed efficient methods for using atomic force microscopes for manipulating nano particles into complex design patterns and for nano indentation for complex lithography. The research contributions thus far are described below.

- Automated nano particle manipulation We have developed an efficient method for using atomic force microscopes (AFMs) for efficiently manipulating nanoscale particles for forming complex pattern. A method, called sequential parallel pushing (SPP), has been developed for efficient and automated nanoparticle manipulation. Experimental results show that the SPP algorithm, when compared with simple target-oriented pushing algorithms, not only reduces the number of scan lines but also decreases the number of pushing iterations. The SPP method has been successfully applied to fabricate designed nanoscale patterns that are made of gold (1015 nm diameter) particles and of 170 latex 50nm diameter particles.
- Integrating CAD and Nano-Indentation for Complex Lithography We present an approach for producing complex nanoscale patterns by integrating computer-aided design (CAD) geometry processing with an atomic force microscope (AFM) based nanoindentation process. Surface modification is achieved by successive nano-indentation using a vibrating tip. By incorporating CAD geometry, this approach provides enhanced design and patterning capability for producing geometric features of both straight lines and freeform B-splines.

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