AFM-Based Nanofabrication: Modeling, Simulation, and Experimental Verification

Rapeepan Promyoo and Hazim El-Mounayri

Department of Mechanical Engineering

Kody Varahramyan

Department of Electrical and Computer Engineering,

Purdue School of Engineering and Technology

Indiana University – Purdue University Indianapolis

Abstract

Recent developments in science and engineering have advanced the fabrication techniques for micro/nanodevices. Among them, atomic force microscope (AFM) has already been used for nanomachining and fabrication of micro/nanodevices. In this research, a multi-scale computational model for AFM-based nanofabrication processes is being developed. Molecular Dynamics (MD) technique was used to model and simulate mechanical indentation and scratching at the nanoscale. MD simulation represents itself as a viable alternative to the expensive traditional experimental approach, which can be used to study the effects of various indentation variables in a much more cost effective way. The effects of workpiece materials, AFM-tip materials, AFM-tip radius, as well as crystal orientations were investigated. The simulation allows for prediction of the indentation forces at the interface between an indenter and a workpiece. Also, the MD simulation was used to study the effects of speed on the indentation force. The material deformation and indentation geometry are extracted based on the final locations of atoms, which are displaced by the rigid indenter. Material properties including modulus of elasticity and friction coefficient are presented. AFM was used to conduct actual indentation and scratching at the nanoscale, and provide measurements to validate the predictions from the MD simulation. Qualitative agreement was found between the simulation and actual AFM-based nanomachining.