ABSTRACT

Plowing is one of the fundamental material removal methods in nanomanufacturing processes. It is typically performed using atomic force microscopes (AFM), where a sharp nano-sized tip mounted at the free end of a flexible cantilever mechanically indents or scratches the substrate to form desired patterns. Unlike macroscale cutting processes, nanoscale plowing involves many uncertainties. The depth-of-cut of the plowed profile depends on many factors including the stiffness of the plowing cantilever and the substrate, thermal drift, and the tip sharpness which are usually unknown parameters. Hence obtaining a desired depth-of-cut is challenging, and often involves cumbersome calibration and trial-and-error process to get a required depth-of-cut. This paper discusses a real-time process control scheme to regulate the depth-of-cut irrespective of process uncertainties. Since closed loop control requires measurement (feedback) of the actual depth-of-cut, this control scheme is designed to be implemented on a dual-probe AFM (DP-AFM). DP-AFM has two independently controlled probes, where one probe can be used for plowing while the other can be used for measuring the plowed profile. Numerical simulations show that the process can be made robust to process uncertainties through proper choice of control gains. Experimental results demonstrate the depth-of-cut can be regulated with nanometer lever accuracy.

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