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Sensitivity Analysis of Load Carrying Capacity in AFM-based Manipulation

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Abstract

In this paper, the sensitivity of cantilever parameters on load carrying capacity in nanomanipulation process is investigated for atomic force microscope (AFM) nanorobot. Due to limitations in real time control for nanomanufacturing process, predicting possibility of the manipulation process is desirable. Main limitation caused by cantilever's geometry. Considering the relationship between cantilever twist angle with its geometry, maximum allowable particle size and therefore load carrying capacity can be found. Finally the effect of variation of four geometrical parameters such as cantilever's length(L), width(W), thickness(T) and probe's height(H) on load carrying capacity is estimated and also simulated, in order to design and choose appropriate cantilever for accurate and successful pushing and assembly purposes.

Key words: **Sensitivity Analysis ,Atomic Force Microscope, Load Carrying Capacity**

1. Main text

Atomic force microscope has been extensively used for surface scanning and imaging but recently it becomes one of the most effective manufacturing processes by concerning the interactions between atomic and molecular sized objects in nanotechnology [1]. Manipulation and assembly of nanoparticles have garnered widespread interest for the last few years and controlled manipulation with atomic force microscope is one of the most popular methods in the manipulation process.

By increasing in the usage of AFM as a nanomanipulation tool and limitations made by cantilever geometry for predicting possibility of the manipulation process, it is reasonable to use sensitivity analysis as a reliable tool to evaluate the effect of each parameter while the others are also changing. Sensitivity analysis may be conducted here to determine the model resemblance with the factors that mostly contribute to the output variability[2-4]. In this Paper, sensitivity of parameters in AFM-based nanomanipulation, including load carrying capacity versus changing all parameters of the nanomanipulation process is estimated for a safe manipulation.

Considering both adhesion and normal friction forces and pull-off forces using the Johnson–Kendall–Roberts (JKR) contact mechanics model, dynamic equations are developed based on the free body diagram of the pushing

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system including AFM cantilever and probe, nanoparticle and substrate [5,6]. Angular velocity (θ), which is considered as our reference to find possibility of manipulation, can be found according to its relationship with linear velocity [7]. These simulations are done for cantilever's thickness and length and width and probe's tip's height.

Maximum allowable particle size depends on two parameters which are force–time diagram and cantilever's structure's resistance changes. Both of these parameters depend on cantilever geometry; therefore, with variations in geometry, they will change. Sensitivity of maximum allowable load is obtained based on simulations, which could improve understanding of the nano-manipulation process and nano-assembly. However, geometrical variations do not have the same effect. As a result of this fact, variations in some geometrical parameters make no difference in particle size, but in some other parameters, it causes a big change. With simulating these effects, probe's tip's height (H) is found as the most effective parameter, and thickness changes in cantilever is considered as the least effective parameter.

Therefore, we find possible condition for manipulation and most possible condition for safe manipulation in order to design and choose AFM geometry with controlled force to prevent destruction of nanoparticles. Existing investigations are verified derived issues of program.

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