MECHANICAL ENGINEERING STUDENT SEMINAR

Wednesday, May 15 2024 at 13:30, D. Dan and Betty Kahn Building, Room 217.
Online: https://technion.zoom.us/j/91370096135

Model based topography identification using Autoresonance control

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In this seminar, I introduce a model-based method to accurately and robustly measure samples' topography using Atomic Force Microscopy (AFM) sensing. Model-based AFM allows for faster and more accurate measuring, negating unwanted effects such as smearing.

Atomic Force Microscopy (AFM) is used to measure atomic-scale geometries by utilizing interactions between the measured specimen and a resonating beam's tip. Classical methods involve exciting a micron-sized cantilever at a frequency close to resonance, and measuring its amplitude and phase. By changing the distance of the tip from the sample and tracking these parameters, it is assumed that the amplitude or phase will reach predetermined reference values at a constant distance from the sample. Thus, using close-loop control, the sample topography can be measured. However, this methodology can be slow due to control loop dynamics. Additionally, the underlying assumption that the tip is coupled to a single point on the topography is inaccurate, as atomic interactions are generally distributed. This problem intensifies when measuring complex geometries, such as grooves and trenches, where the interactions are highly distributed along the sensing element and therefore the recovery of topographic features involved coupled and nonlinear equations that are difficult to solve.

The proposed Model-based sensing method incorporates the Autoresonance (AR) technique to sense the AFM sensor's change in resonance frequency due to interactions with the measured surface, as the natural frequency is a parameter that can be analytically modeled. A model for the VdW interactions between a vibrating nanowire and a groove-shaped sample was formulated, and the natural frequency of the nanowire was constantly measured while incrementally inserting the nanowire into the groove, allowing precise measurement of the VdW potential induced by the groove on the nanowire. To decouple the nonlinear distributed interactions between the nanowire and the groove, an iterative approximation method was developed. This method utilizes a simplified model to converge to the exact solution of the full model

An alternative approach of the widely used Tapping Mode AFM excited using AR was developed. A hybrid model was used to derive an analytical relation between the distance of the beam from the sample and the vibration frequency of the beam. Using this relation, the distance can be easily obtained.

Numerical simulations and experimental systems were constructed to validate the model and methodology, producing and accurate reconstruction of the sample topography.

Note: the seminar will be given in English

Seminars Coordinator: Assoc. Prof. Gal Shmuel