Modal actuation for high bandwidth AFM imaging

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Abstract

In high speed atomic force microscopy, the topography of a sample is imaged on a nanometer scale by measuring the deflection of a cantilever which is in contact with the sample surface through a sharp protruding tip. To avoid damage to sample or tip, the cantilever deflection is regulated by tracking the sample topography using a feedback control system. In high speed AFMs, the bandwidth of the vertical axis positioning system is a limiting factor. The dynamics of the piezoelectric actuator, its support structure and load play a dominant role in the design of the feedback loop. A common problem in the design of such control systems is the excitation of resonant modes which are close to the controller bandwidth. A possible solution to this problem is the application of a modal actuation using a modal pre-filter. In this approach the shape of the electrodes of the piezoelectric actuator are modified by etching or by the application of electrodes of varying porosity. In both cases, the electric charge varies along the vertical axis of the actuator as a function of the mechanical mode shape of the actuator assembly (actuator, mount and load). In this way only a single mode or subset of modes is actuated. A drawback of this approach is that the solution is static and can not adapt to changes in mode shapes caused by varying load conditions. In applications where the system dynamics are subject to change due to the introduction of additional loads, this may lead to unwanted oscillations or instability. To avoid poor stability robustness of the feedback control system, the actuator electrode is sectioned rather than shaped and modal actuation is achieved by applying voltages of different amplitudes to each section. The ability to adjust the amplitudes of the voltages applied to each section allows in situ tuning of the modal filter to match variation in mode shape. In this contribution the tuning of modal actuators to account for load variations is investigated and the in situ tuning approach is compared to a robustness approach where the modal actuator is based on fixed voltage amplitudes tuned for a worst case load variation.