Chapter 3
Advanced Vibration Control of Atomic Force Microscope Scanner

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ABSTRACT
Atomic Force Microscopes (AFMs) are used in many nanopositioning applications in order to measure the topography of various specimens at an atomic level through surface imaging. The imaging of the samples in AFMs is carried out by using a three degree-of-freedom positioning unit called Piezoelectric Tube Scanner (PTS). The performance of the AFM mostly depends on the performance of the PTS. However, the PTS of the AFM suffers from the problem of vibration. This chapter presents a design of a damping controller to compensate the induced vibration of the scanner. Experimental results are presented to show the effectiveness of the proposed controller. The experimental results show that the proposed controller is able to compensate 90% of the vibration of the PTS.

1. INTRODUCTION
Scanning probe microscopy (SPM) (Binning et al., 1986; Meyer et al., 2004) refers to a group of imaging techniques that collect images of sample surfaces through scanning. Many types of SPM systems such as scanning tunneling microscope (STM) (Binning et al., 1987), atomic force microscope (AFM) (Bhikkaji et al., 2008; Das et al., 2012; Ratnam et al., 2005), and magnetic force microscope (MFM) (Rugar et al., 1990) are used now a day to view sample surfaces. The SPM was first found in the form of STM. The STM uses only conducting samples to scan which limits the use of STM for non-conducting samples. This leads to the invention of the AFM. The AFM is a type of SPM system which is used to measure the DOI: 10.4018/978-1-4666-7248-2.ch003
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Figure 1. Basic component of the AFM system

The atomic force microscope (AFM) is a high-resolution imaging technology that allows the topography of various specimens down to atomic level. The AFM generates three dimensional images of both conducting and non-conducting samples in vacuum and non-vacuum environments.

G. Binning and his colleagues invented the AFM in the year of 1986 based on their design of STM. The AFM is also known as scanning force microscopy (SFM). Since from the invention the AFM has emerged as an important tool in nanotechnology research. The AFM can be used in the vacuum and non-vacuum environments. It can also operate at different temperatures.

In the imaging process of the AFM a sharp tip is used to scan the sample. The tip is brought into the closed proximity of the sample. The AFM works based on the interactive forces between the tip and sample surface. The interactive forces include various kinds of forces such as capillary, van-der-Waals, electrostatic and magnetic. These forces are composed of long and short range components.

The basic component of the AFM system is illustrated in Figure 1. The AFM consists of a cantilever with a sharp tip, a laser source, a laser photo detector, and a scanner called piezoelectric tube scanner. The sample is placed on the scanner during the imaging process. A capacitive sensor is placed with the scanner to measure the displacement of the scanner. When the cantilever is brought close to the sample surface at a distance in the order of few nanometers or less, the cantilever tip deflects. The deflection of the cantilever is measured by the photo detector. Depending on the amount of the deflection of the cantilever an image of the sample is generated.

There are basically two operating modes of the AFM and the modes are static and dynamic modes. The static mode measures the interactive forces by using static bending of the micro cantilever. In the dynamic mode the cantilever is excited at its resonance frequency. Static mode is also known as contact mode or repulsive mode. In contact mode the sample and cantilever tip are placed very close to each other nearly few Angstroms. The interactive force works in contact mode is the repulsive force.

The resolution of the scanned images in static mode is limited by the tip-sample contact area which is typically in the range of 1-10 nm. In order to obtain good image of the sample it is required that the tip is placed within tenth of a nanometer to the sample surface. However, it is difficult to achieve such a tip-sample distance in static mode. In this mode the tip exerts a large lateral force from the sample surface which can break the tip of the cantilever. This mode is also not suitable to scan soft biological sample.

Dynamic mode of the AFM is of interest because of its non-contact nature between the sample and tip of the cantilever. In this technique the tip does not remain contact with the sample. The interactive