ABSTRACT

Nanotechnology is supposed to become the key technology of 21st century. The field of nanotechnology is emerging and expanding and applicable to diverse domain of physical systems. It is the understanding and control of matter at the nanoscale i.e. dimensions between 1 and 100 nanometers, where unique phenomenon enables novel applications. The engineering research in nanotechnology is expected to lead to breakthrough in the areas such as health care and medicine, advanced materials, electronics, manufacturing, biotechnology, defense etc. It is widely recognized that one of the key requirement of nanotechnology is the nanopositioning.

Nanopositioning is the precision control and manipulation of devices and materials at nanoscale with incredible accuracy. Nanopositioners are precise mechatronic systems designed not only to move or position a probe, part, tool, sample, or device at some desired position with nanometer accuracy and repeatability but also to resolve adjacent positions that are separated by less than a nanometer. The desired performance characteristics of a nanopositioner are precise positioning, long travel range, extremely high resolution, accuracy, wide bandwidth, stability, fast response with very small or no overshoot and robust closed loop position control. To achieve all these characteristics, a large number of nanopositioning system geometries have been available.

A nanopositioning system is an assembly of precise detection system, solid state smart actuators driven by the control systems and monolithic motion guide stage. In order to realize precise positioning at sub nanometer resolution, all these elements are to be carefully designed, analyzed and optimized. For highly accurate and high speed nanoscale positioning applications, recently, nanopositioning systems based on the piezoelectric stack actuators using flexure guided mechanism have been developed.

Although the piezoelectric actuator based nanopositioning systems are designed to provide greatest possible accuracy and unlimited resolution, but in practice they exhibit inherent non ideal characteristics such as creep, hysteresis and vibration effects that severely degrade its performance. In addition to these
nonlinearities, the performance characteristics of nanopositioning system are highly affected by mechanical dynamics/design of the motion stage, external disturbances and drift due to the temperature variation. To reduce inherent nonlinearities of piezoelectric actuator and to improve nanopositioning system performance, control plays an important role. The performance analysis of control system focuses on time domain characteristics such as maximum overshoot, rise time, settling time and steady state error and frequency domain characteristics such as phase and gain margins.

This thesis is intended to address the major issues of the modeling and control of nanopositioning system. Further, investigation and development of the feedback control schemes to achieve satisfactory system performance i.e. good time response and frequency response characteristics have also been done. Design and implementation of conventional controllers, state feedback controllers and robust controllers for nanopositioning system have been done to achieve better system performance. Simulated results of different controllers are compared and it has been analyzed that the performance characteristics of the nanopositioning system have been improved. It has been concluded that different type of controller works well for different conditions and applications. The simulated results are obtained in MATLAB environment. The present work can be further extended to investigate modeling and control of nanopositioning system including non-linearities, control of multi axes nanopositioning system and real time application of nanopositioning system in future.