Chapter 6
PZT Driven Micro XY Stage

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Abstract  Novel piezo-driven XYZ and XY microstages have been developed. The design, fabrication and evaluation of the two kinds of microstages are presented. One of the microstages is fabricated from a monolithic PZT plate. Using dicing, electroplating of nickel, photolithography and laser machining, stacked PZT actuators are formed in the PZT plate, also the structure of XYZ microstage with 16×15 mm² are defined. This microstage has a capability of 6 degrees of freedom in motion. Using capacitive displacement sensor, precise motion control is demonstrated. However, it is difficult to form support spring with a low stiffness due to the difficulty in the structure formation of PZT. Another type of the microstage is hybrid of Si and PZT, a Si XY microstage structure is formed by deep reactive ion etching, and PZT stacked actuators are assembled in to the Si microstage. In order to amplify the displacements, Moonie amplification mechanism is chosen. The stage is supported by the Moonie mechanism and support springs. Over 80 μm of displacement is obtained at an application voltage of 70 V, also 18 times amplitude amplification is demonstrated.

6.1 Introduction

With the development of nanotechnologies, the importance of nanopositioning technology is increasing for various applications including nanoindentation, nanolithography, scanning probe microscopy and atomic force microscopy (AFM) based high-density data storage devices, etc. The PZT(Pb(ZrTi)O₃)-powered microstage,
one of the nanopositioning devices, has attracted considerable attention from many researchers owing to its merits such as small size, high stiffness, high resolution, fast response, low power consumption, relative large output force and frictionless actuation. The need for better nanopositioning devices will continue as the research and technology in the micro/nano world becomes more rapid. Therefore, quite a number of researches concerning micro/nano positioning for various applications such as data storage systems [1,2], micro-optical systems [3], and various measurement devices can be found [4,5].

The developed micro/nano positioning devices utilize different types of actuation methods. Pantazi et al. [6] and Golda et al. have developed a microstage driven by electromagnetic microactuators for probe-based data storage application [7]. Xu et al. have developed a microstage with PZT actuators [8], Sasaki et al. is working on electrostatically driven XY-stages [9]. A majority of the microfabricated XY-microstages are based on electrostatic and electromagnetic actuation. This is due to the long travel range offered by these two types of actuators compared to other type. However, the drawback of the electrostatic actuator is its low energy density [9]; therefore, a large array of comb drive actuators is required in order to produce a high output power, resulting in a large overall size of the XY-stage. In the case of electromagnetic actuation it is difficult to integrate actuators using microfabrication technology since it requires 3 dimensional coil structures and deposition of magnetic materials [6, 10].

There are few researches that have been executed using piezoelectric microactuators for nanopositioning, but none have succeeded to produce large enough displacements for practical use. The advantages of piezoelectric actuators are their relatively high operating frequency, high energy density and high accuracy with sub-nanometer resolution.

The aim of this research is to develop a microstage which is able to produce a large displacement, high accuracy, a large stage area and high resonant frequency with low cost.

The designs and fabrications of two kinds of PZT-driven XY microstages are reported. Laboratory-made stacked PZT actuators are employed for actuation. The actuation performances of the XY-microstage are evaluated.

6.2 Monolitic PZT XYZ Microstage

6.2.1 Design of Monolitic PZT XYZ Microstage

A monolithic PZT XYZ microstage is proposed and fabricated. Using a novel fabrication method for integration of PZT actuators into monolithic PZT, multi-degrees of freedom in the motion of microstage can be achieved. In addition, capacitive sensors for position monitoring can be integrated.