MECHATRONICS BOOK SERIES

CONTROL AND INTELLIGENT SYSTEMS

Momoh Jimoh E. Salami
Abiodun Musa Aibinu
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IIUM Press
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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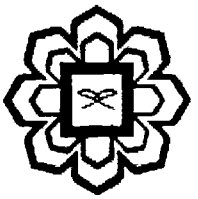

IIUM Press

Published by:
IIUM Press
International Islamic University Malaysia

First Edition, 2011
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Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Momoh Jimoh E. Salami, Abiodun Musa Aibinu, Yasir Mohd Mustafah: Mechatronics Book Series: Control and Intelligent Systems
Bibliography p.
Includes Index
ISBN

ISBN: 978-967-418-176-5

Member of Majlis Penerbitan Ilmiah Malaysia – MAPIM
(Malaysian Scholarly Publishing Council)

Printed by :
IIUM PRINTING SDN.BHD.
No. 1, Jalan Industri Batu Caves 1/3
Taman Perindustrian Batu Caves
Batu Caves Centre Point
68100 Batu Caves
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Chapter 14
Piezoelectric Tube Scanner in Atomic Force Microscope

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14.1 Introduction

This chapter describes an in-depth description of a piezoelectric tube scanner which is a critical component in AFMs. This description encompasses the construction and mechanic of the scanner and three major effects that limit the positioning precision of the scanner especially for high speed AFM and long scanning range operations namely hysteresis, creep and vibration. The discussion also includes distortions observed in AFM images as results of these effects.

14.2 Piezoelectric Tube Scanner

The use of the piezoelectric tube as a 3D scanner was first proposed in Ref. [1] to replace the use of tripod scanner in STM. The piezoelectric tube scanner was found to provide a faster response and a better positioning precision in comparison to the tripod scanner owing to its simpler and smaller construction. The piezoelectric tube scanner typically consists of a cylindrical tube made of radially poled piezoelectric material fixed at one end and free at the other. The piezoelectric tube is plated with a layer of electrode on the inner and outer surfaces of the tube. As shown in Figure 14.1, the inner electrode is continuous and grounded, and the outer layer electrode is segmented into four equal sized electrode sectors of 90 degrees referred individually as +x, −x, +y, and −y electrodes. However, the top part of the external electrode is not segmented. It is left as a circumferential electrode referred as +z electrode. Aluminum or a stainless steel cube is fixed to the top of the tube to serve as a sample holder and also to provide capacitive sensors flat surfaces so that the tube deflection can be measured accurately in the case of a closed-loop scanner.

The motions of the scanner in the x axis and y axis are each controlled by a pair of external electrodes, +x, −x and +y, −y electrode pair respectively, that are driven by voltage signals of the equal magnitude but with opposite signs. When these voltage signals are applied to the electrode pairs, the piezoelectric material underneath those electrodes will expand or contract radially depending on the polarity of the applied voltage signal with respect to the polling direction of the piezoelectric material. If the polarity of the voltage signal coincides with the polling direction, the piezoelectric material will expand in the radial direction and causes the tube to reduce in length. If the polarity of the voltage signal is opposite to the polling direction, the piezoelectric material will contracts in the radial direction and causes the tube to increase in length. As opposite voltage signals are always applied to each electrode pair, the length of the tube on one side of the electrode pair will reduce, while the length on the opposite side will increase. This leads to a bend in the tube which produces a lateral deflection of the tube's free end in the x or y axis. The motion of the scanner in the z axis is