Fabrication and Characterization of Magnetostrictive Micro-cantilevers

Jitendra Singh[1*], Ramesh Kumar[1], Aditi Sinha[1], Surajit Das[1], Deepak Panwar[1], Chelvane J. Arout[2]
[1]*Smart Sensors Area, CSIR-Central Electronics Engineering Research Institute Pilani, Rajasthan 333031, India*
[2]*Advanced Magnetics Laboratory, Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad 500058, India*

*E-mail: jitendra@ceeri.res.in

Abstract— **We have developed a magnetostrictive $Fe_{65}Co_{35}$ thin film based micro-cantilevers using micro-fabrication process. The cantilever stack consists of $Si/SiO_2/Fe_{65}Co_{35}$ layers for actuation and thickness was controlled by silicon bulk micromachining process. High magnetostrictive and low stress Fe/Co 65/35 composition was utilized in cantilevers. Magnetic properties of $Fe_{65}Co_{35}$ films were investigated using vibrating sample magnetometer and laser Doppler vibrometer. Micro-cantilever dimensions were confirmed using scanning electron microscope. Magnetic actuation was performed by applied magnetic field of 2000 Oe and tip deflection was monitored using laser interferometry method. In-house dc magnetic field set-up was developed which is compatible to laser Doppler vibrometer. Using cantilever deflection method magnetostriction coefficient (λ) was found to be 135 ppm. The developed magnetostrictive cantilever is very useful MagMEMS and low field sensing and actuation applications.**

Keywords—cantilever; magnetic; MEMS; magnetostrictive

I. INTRODUCTION

Magnetostriction is a property of magnetic material and shape of material changed under the influence of external magnetic field. This property of material is very useful for development of magnetic micro-electro-mechanical systems (MagMEMS), because magnetic energy can be directly converted into mechanical energy and vice-versa. Highly efficient sensors and actuators can be developed using magnetostrictive materials. The major advantages of MagMEMS are remote control operation, compatible with semiconductor fabrication process and possible integration with microelectronic technology. Small size, light weight and low cost MagMEMS devices are possible to realize. Thin layer of magnetostrictive material can be used in MEMS micro-cantilevers structure and actuated by magnetic field. Deflection and bending of cantilever are the key actuation mechanism. The MagMEMS have variety of applications in switches, valves and laser beam deflectors etc.

Figure 1 show the schematic sketch of composite micro-cantilevers which has been fabricated using a bulk micromachining process. The cantilever stack consists of $Si/SiO_2/Fe_{65}Co_{35}$ layers. Si was the base layer and SiO_2 work as a isolation layer to separate $Fe_{65}Co_{35}$ from Silicon. High magnetostrictive composition of iron-cobalt was utilized in the sensor for higher deflection of cantilevers. Magnetic field was applied along the X- and Z- directions to actuate the cantilevers. Magnetic field induced deflection was monitored using laser Doppler vibrometer white light interferometry. The cantilever materials properties are listed in Table I. Magnetostrictive layer $Fe_{65}Co_{35}$ was uniformly distributed on top of cantilever.

II. EXPERIMENTAL PROCEDURE

A. Micro-cantilever fabrication process

Magnetostrictive MEMS micro-cantilever structures are fabricated using a 3-inch diameter double side polished Si(100) wafers. The processing of mass sensor consists of two major steps: 1) fabrication of Si/SiO_2 composite cantilever, and 2) deposition of magnetic $Fe_{65}Co_{35}$ layer.

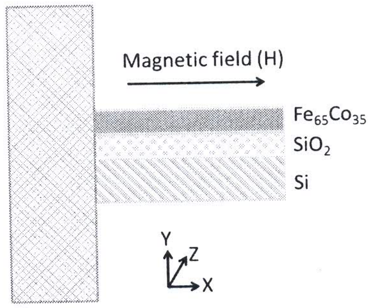

Fig.1. Schematic sketch of magnetostrictive micro-cantilever.

The complete process is composed of two photolithography steps as shown in figure 2. Initially, Si wafers were cleaned using standard semiconductor cleaning process. Now, wafers are loaded in thermal oxidation furnace for growth of thermal silicon dioxide (SiO_2) ~1µm using a dry-wet-dry process sequence (step 1). Here, SiO_2 layer work as a masking layer during Si bulk micromachining during tetra-methyl-ammonium hydroxide (TMAH) etching and also works as an isolation layer between underlying Si and active magnetostrictive $Fe_{65}Co_{35}$ layer. Mask #1 was used to pattern SiO_2 layer and wet etched was performed. Now, silicon windows are opened which will be later used for bulk micromachining process at later stage. Mask #2 was used to define area of cantilever and top side release. Top side SiO_2 was etched using wet etching proves. Now wafer is loaded in wafer protection jigs for one side TMAH bulk micromachining of Si wafers. Si/SiO_2