Tunable Film Bulk Acoustic Wave Resonator Based on Magnetostrictive $Fe_{65}Co_{35}$ Thin Films

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Abstract — **We have developed a Tunable Film Bulk Acoustic Wave Resonator (TFBAR) based on magnetostrictive $Fe_{65}Co_{35}$ thin films. The resonator layer stack consists of Pt/ZnO/$Fe_{65}Co_{35}$ layers for tuning of devices. When resonator is subject to magnetic field there is expansion in $Fe_{65}Co_{35}$ layer due to magnetostrictive effect. This expansion in $Fe_{65}Co_{35}$ layer induces strain, which alters the Young's modulus of magnetostrictive layer and this behavior is denoted as ΔE effect. In an unbiased condition, series (f_s) and parallel (f_p) resonance frequency are detected at 1.14 GHz and 1.187 GHz, respectively. When resonator was placed in magnetic field series and parallels both resonance frequencies are lower shifted by ~7MHz. Electromechanical coupling coefficient (k_t^2) was found 9.69% when there is no magnetic field and reduced to 9.53% with magnetic field. This reduction in k_t^2 is due to magnetic field induced strain in magnetostrictive $Fe_{65}Co_{35}$ layer. The proposed resonator is very promising and can be utilized for various reconfigurable microwave resonators, frequencies agile devices and magnetic sensors.**

Index Terms — **Acoustic resonators, magnetostriction, Piezoelectric devices, MEMS.**

I. INTRODUCTION

Reconfigurable microwave resonator/filters make microwave transceivers adaptable to multiple bands of operation using a single filter, which is highly desirable in today's communications systems with evermore growing wireless applications. Tunable filters can replace the necessity of switching between several filters to have more than one filter response by introducing tuning elements embedded into a filter topology. $Fe_{65}Co_{35}$ thin films show magnetostrictive behavior and elastic modulus can be tuned by applied magnetic field. This effect is also regarded as ΔE effect. Size of RF/Microwave system (cellular radio or mobile phones) is continuously reducing due to competitive market and therefore goal of the RF/Microwave engineer to obtain small size, high performance and low cost reconfigurable integrated devices. Multiple functions are possible with a single tunable microwave resonator. Magnetostrictive $Fe_{65}Co_{35}$ can be integrated with Zinc oxide (ZnO) to maintain high quality factor (Q) and high figure of merit (FOM) with enhanced functionalities. Currently, acoustic wave resonators are available for single frequency of operation. Current progress of microwave communication systems indicates that these system has to be more user friendly i.e. adaptable and reconfigurable. The growing numbers of channels and bandwidth have to be agile (adaptable/reconfigurable). New functionality is needed in devices with enhanced performance to make them agile and cost effective.

Here, FBAR tuning is proposed based on ΔE effect. When resonator is placed in magnetic field, strain can be induced in $Fe_{65}Co_{35}$ thin film due to magnetostrictive effect. This result to a change in Young's modulus of magnetostrictive resonator. Device impedance and electromechanical resonance frequency (fs and fp) were tuned through dc magnetic field. Here, we have proposed a novel tunable film bulk acoustic wave resonator (TFBAR) based on magnetostrictive $Fe_{65}Co_{35}$ thin films.

Figure 1 shows the schematic sketch of Tunable Film Bulk Acoustic Wave Resonator (TFBAR) which was fabricated using bulk micromachining process. The resonator layer stack consists of various SiO_2/Pt/ZnO/$Fe_{65}Co_{35}$ layers. SiO_2 work as an isolation layer to isolate ground and signal electrodes. High magnetostrictive composition $Fe_{65}Co_{35}$ was utilized in the resonator for high tunability. Magnetic field induced frequency shift was monitored using vector network analyzer. The resonator materials properties and thickness are listed in Table I.

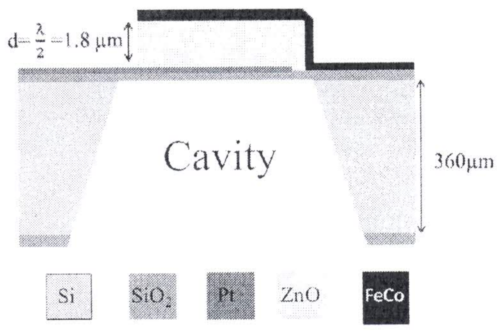

Fig.1. Schematic cross-section sketch of tunable FBAR.

II. EXPERIMENTAL PROCEDURE

Magnetostrictive TFBAR structures was fabricated using a 3-inch diameter double side polished Si (100) wafers. The processing of TFBAR consists of five mask level fabrication process as shown in figure 2.