Design and Implementation of Electrically Tunable Filter on Thin-Films Enabled Engineered Substrate

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***Abstract*— To miniaturize communication systems, great efforts have been spent on developing tunable RF passives. Fully electrically miniaturized tunable RF passives have been implemented with the integration of both ferromagnetic and ferroelectric thin films directly into the individual specific design. This report describes the investigation of coplanar waveguides (CPW) patterned with Permalloy (Py) thin-film to achieve greater inductance tunability through optimal thickness and deposition method, which maximizes its tuning range and RF performance. The developed technology has great applications in the design of tunable filters.**

***Index Terms*—Electrically tunable, ferromagnetic thin film, nanopatterns, radio frequency (RF) components.**

I. Introduction

THE wireless communications market today is evolving rapidly. The newer generation systems work on multiple bands and modes of operation. Therefore, implementation of RF and Microwave circuits, which incorporate multiple cellular modes, is very attractive. With this change, much research effort has been spent on developing tunable components with many different technologies such as switched capacitor networks, ferroelectric films, microelectromechanical systems (MEMS), and ferromagnetic films. Ferromagnetic film such as Permalloy has been explored in developing RF components with inductive tuning capability [1]-[2], however it general requires complex external magnetic bias field and its applications have been limited by the low FMR frequency (<1 GHz). Dr. Wang has demonstrated a strategy in improving FMR frequency of Permalloy to over 6 GHz with nano-patterning methods and developed an equivalent permeability tuning method for Permalloy with DC magnetic field generated with applied DC current. Fully electrically miniaturized tunable RF passives have been successfully implemented with the integration of both ferromagnetic and ferroelectric thin films directly into the design [3], [4] with simultaneous tunable inductance and capacitance.

The efficacy of the proposed engineered substrate has been preliminary demonstrated with Antenna and Coupler on the substrate [5], [6]. In this research, we plan to combine the above two techniques to design, fabricate, and test an electrically tunable filter. Specifically, we will investigate the inductance tunability of the integrated ferromagnetic thin films and the optimal thickness and deposition method of the integrated ferromagnetic films in the design of filter for maximum tuning range and RF performance.

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II. Design And Fabrication

The design structure used to implement the filter was the CPW. Through the simulation of ANSYS HFSS, CPW was designed to have a 50Ω impedance. The length of the CPW was kept constant at 1mm while the width of the signal line was varied at 50, 75, 100, 150, 200, 250 µm and the ground line width at 350, 350, 350, 350, 400, 500 µm respectively as shown in Fig. 1. Py thin films were patterned with dimensions of 5x10, 5x30, 5x50, 10x10, 10x30, 10x50 µm. To compare the difference of inductance density, CPWs with unpatterned Py were also fabricated. Additionally, different thickness of the deposited metals are explored. The thicker deposited materials should result in greater tunable range.

A. Fabrication

To fabricate the devices a titanium layer of 100 nm is deposited on a high resistivity silicon wafer using electron beam deposition. Negative photoresist NR71-3000P is spun onto the wafer at a thickness greater than the desired thickness of the signal line, in this case 2 µm. A copper layer is deposited onto the titanium through electrodeposition in a copper solution. In Fig. 1 the thickness is 1 µm. Electrodeposition is chosen as a deposition method because it allows for very thick deposition in a cost-effective and quick manner. Once the photoresist is removed, another photoresist layer is spun onto the device. Py is then deposited onto the signal lines in micro patterns. Finally, after removing the photoresist the wafer is placed into a remover until the thin titanium layer is removed.

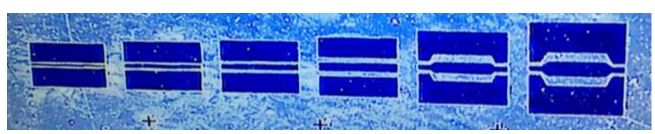

Fig. 1 Optical Photograph of the CPW without Py

III. Measurement

The fabrication of the devices is currently being optimized. Once the fabrication is complete, the on-wafer measurement will be conducted with GSG RF probes. Using the R&S ZVA67 vector network analyzer, the scattering parameter (s-parameter) of the fabrication CPWs will be measured with different biasing dc currents. Using the two ports of the CPW, RF signal and dc bias current is applied simultaneously with bias tees. The measurement setup is shown in Fig. 2. Using the obtained s-parameter the admittance parameter (Y-parameter) can be found through transformation. Through the Y-parameter the inductance can be found as shown in equation 1, where Y_{11} is the reflection Y- parameter at port 1 and f is the frequency.

$$L = Im(\frac{1}{Y_{11}})/2\pi f \tag{1}$$

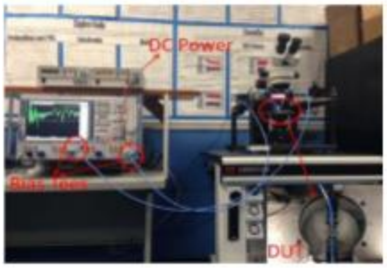

Fig. 2 Measurement setup

On-wafer multiline through-reflect-line calibration [7] will be performed. Therefore, the loss from connecters, cables, bias tees, probes, and parasitics from probe pad are de-embedded. Additionally, as ANSYS HFSS simulation to optimize the impedance was performed. The resulting error from on-wafer measurement will be significantly reduced.

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