Magnetostatic Straight Edge Resonators on Micromachined Silicon Membrane

George Sajin\textsuperscript{a}, Romolo Marcelli\textsuperscript{b}

\textsuperscript{a}National Research and Development Institute for Microtechnologies
32B Erou Iancu Nicolae str., PO Box 38-160, 72996, Bucharest, Romania

\textsuperscript{b}M\textsuperscript{2}T - Microwave Microsystems Technology, CNR-IMM, Rome Section
Via del Fosso del Cavaliere 100, 00133 Rome, Italy

ABSTRACT

A frequency tunable magnetostatic wave (MSW) straight edge resonator (SER) made by a YIG film has been used as a selective frequency component in a micromachined resonating filter. S-parameters have been measured at different DC magnetic bias fields, with a frequency tunability between 2 GHz and 6 GHz ca.. An improvement of the performances for the SERs excited by micromachined microstrip transducers has been clearly demonstrated. Moreover, the utilization of silicon membranes to support MSW-SERs offers important openings toward the integration of magnetostatic wave devices with micromachined structures.

Keywords: Straight edge resonator, Silicon membrane

1. INTRODUCTION

Planar magnetostatic wave (MSW) technology is well known for providing frequency tunable filters and oscillators for linear and nonlinear microwave signal processing\textsuperscript{1-4}. The size of MSW resonators is chosen to fulfill the conditions of good electrical matching and frequency selectivity of the resonator. MSW resonators in band-pass configurations are placed between two microstrip transducers with side-coupling for both the input and the output microstrip. In this paper, two configurations have been studied: (i) a bulk one with the two microstrips realized on a silicon substrate and (ii) a micromachined one with transducers having the same geometry but suspended on a membrane obtained by silicon substrate etching.

2. DEVICE CONSTRUCTION

In our experiment we have used two kinds of 4000 $\Omega$.cm silicon substrate: a 400 $\mu$m thick bulk silicon and a 50 $\mu$m thick silicon membrane. Silicon permittivity was $\varepsilon = 11.7$ enabling a $w_0 = 500$ $\mu$m feeding microstrip lines in order to obtain a 50 $\Omega$ impedance at the device ports.

The transducers width/length dimensions were 50 $\mu$m/4 mm. The transition between transducer lines and feeding microstrip lines have a progressive impedance change to provide a wideband operation for the SER. Cr/Au followed by Au electroplating was used for the microstrip transducers, up to a 1.5 $\mu$m of thickness\textsuperscript{5}.

Two rectangular samples of epitaxial YIG/GGG layer were used. Dimensions were: sample #1: 4x0.5x0.32 mm$^3$ and sample #2: 4x0.4x0.32 mm$^3$. The same YIG/GGG chips were used in all experiments. The thickness of GGG support substrate was 0.30 mm and the thickness of active YIG
layer was 0.020 mm. The microprocessed silicon substrate, the resonator structure and the test fixture are presented in Fig. 1. For device construction see, also, Fig. 1.

Figure 1. (a) The microprocessed silicon substrate, (b) The resonator structure, (c) Microwave test fixture.

3. EXPERIMENTAL RESULTS

The resonators were biased by means of a DC magnetic field whose strength was changed to provide frequency tunability from 2 GHz to 6 GHz ca. The $S_{21}$ parameter was recorded to compare the performances of the bulk and micromachined structures by using two YIG resonators having different sizes.

In Fig. 2 and Fig. 3 the measurements of the two YIG samples on the bulk substrate are shown. The level of losses is quite high, close to -20 dB, and a high order mode appears not far from the main one. The operative range is between 2.5 and 4.5 GHz, approximately. In Fig. 3 similar results are obtained, when sample #2 is investigated: the losses are still high, but there is only one high order mode which enters the spectrum and it is depressed 10 dB ca. with respect to the main mode.

Figure 2. Transmission characteristics for the silicon bulk MSW-SER, sample #1. The strength of the dc field is given close to each resonance peak for the main mode. The rejection ratio (RR) is greater than 20 dB, but higher order modes enter the spectrum, affecting the spectral purity of the resonator. The losses are close to -20 dB.
Passing to the micromachined configuration (see Fig.4 and Fig.5), two main differences can be seen as compared to the bulk one. First, the 50 Ω matching condition for microstrips is valid also in the coupling region and this solution allows a losses level less than 10 dB in $S_{21}$. The isolation is better than 30 dB. Secondly, the micromachining of the Si wafer has caused a shift of the operative frequencies available for the resonator and a widening of the operative range.

**Figure 3.** Transmission characteristics for the bulk MSW-SER, sample #2. An improvement in the selectivity is recorded because of the different dimensions of the resonator.

**Figure 4.** Transmission characteristic for the MSW-SER on membrane, sample #1. Losses are now between -10 dB and -7 dB within the operative range.
4. CONCLUSIONS

Bulk and micromachined magnetostatic wave resonators have been characterized and the enhancement of the electrical performances for the micromachined structure with respect to the bulk one was demonstrated. Four SER configurations, two on a silicon bulk substrate and other two on silicon membrane, were measured. The obtained results demonstrate both: (i) the possibility to combine the MSW technology with the micromachining one, and (ii) the improvement obtained by the resonators supported on silicon membrane, with a decrease of 18 dB ca. in the insertion losses.

REFERENCES