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Feasibility Study of ZnO-Based FBAR Devices for Mobile WiMAX Applications

Linh Mai[1], Jae-young Lee[1], Van-su Pham[1], and Giwan Yoon[1]

[1]Information and Communications Univ., School of Engineering, Communication Electronics Laboratory,
119, Munjiro, Yuseong-gu, Daejeon 305-732, Korea
Phone: +82-042-866-6201 Fax: +82-042-866-6227
E-mail: {mailinh, jae0229, vansu_pham, gwyoon}@icu.ac.kr

1. Introduction

Recently, the Worldwide Interoperability for Microwave Access (WiMAX) technology has been known to be able to bring the wireless and internet technologies to portable devices. In particular, the 2.3–3.6 GHz band is assigned for mobile broadband WiMAX applications [1]. On the other hand, the film bulk acoustic resonators (FBAR), one of resonant piezoelectric devices, have been well-known to resonate in a few GHz frequency regimes. Basic FBAR comprises a piezoelectric film sandwiched between top and bottom metal electrodes. When an RF signal is applied across the device, it produces a resonance [2]. The solidly mounted resonator (SMR) [3], a type of FBAR, has a Bragg reflector (BR) that can act as a mirror to isolate any possible energy loss from piezoelectric layer into the substrate, thus allowing the FBAR device to have even higher quality factor (Q). Bragg reflectors in conventional SMR-type FBAR devices have been fabricated by alternately depositing both high and low impedance materials.

In this paper, the feasibility study of FBAR devices for WiMAX applications is experimentally studied. Also, a new device fabrication technique is presented that could improve the resonance characteristics of the FBAR devices by inserting very thin chrome (Cr) adhesion layers between tungsten and silicon dioxide (W/SiO_2) in a multilayer Bragg reflector. In addition, any possible effects of the bottom electrode thickness variation on the device characteristics were also investigated.

2. Experiments

The FBAR devices are prepared as follows. Multilayer BR of the FBAR device was formed by depositing thin film layers of SiO_2, Cr, W, SiO_2, Cr, W, and SiO_2 on three 4-inch p-type (100) silicon wafers (named S1, S2, and S3). SiO_2 layer (0.6 µm-thick) was deposited by a chemical vapour deposition (CVD) technique. Cr (0.03 µm-thick) and W (0.6 µm-thick) layers were deposited by using a sputtering technique. Then, 0.3, 0.8 and 1.2 µm-thick aluminum (Al) bottom electrodes (as floating ground) were deposited on the three wafers S1, S2, and S3, respectively, followed by 1.2 µm-thick ZnO film deposition on these wafers. Finally, the deposition and patterning of the top electrodes (0.2 µm-thick Al) on ZnO film completed the FBAR devices fabrication. Fig. 1 shows cross-sectional SEM image of the Bragg reflector and the schematic structure of FBAR device.

Two resonator layout patterns (1 and 2) were designed for testing the resonance characteristics. The return loss (S_{11}) characteristics were extracted from the resonance patterns on each of the three wafers (S1-S3) by using a probe station and Hewlett Packard/HP 8722D network analyzer.

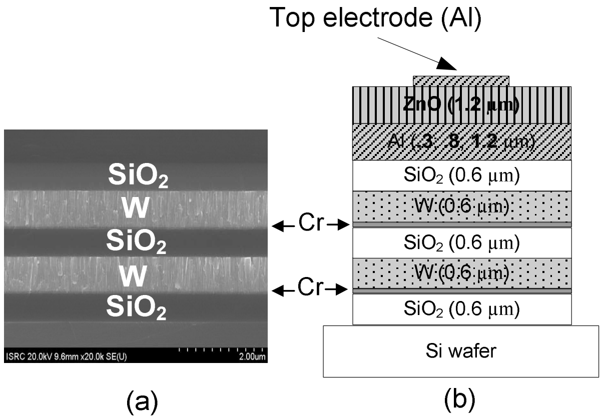

Fig. 1 FBAR device structure: (a) SEM image of BR; (b) Cross-sectional view.

3. Results and Discussions

Fig. 2 shows two resonator patterns and their return loss characteristics versus frequency for various bottom electrode thicknesses. Fig. 2 (a) and (b) compare the return loss characteristics of the FBAR devices with the resonator patterns 1 and 2 with the Al bottom electrode (0.3 µm-thick, 0.8 µm-thick, and 1.2 µm-thick, respectively). The S_{11} values of the two resonators fabricated on S2 and S3 samples show the same increasing trend in comparison with that of resonators on S1. Clearly, the resonators with the thickest bottom electrode of Al have the largest return loss characteristics. The resonators on S1, S2, and S3 samples have S_{11} = -18.64 dB, -22.40 dB, and -26.65 dB, respectively. All the extracted values S_{11} of the two resonator patterns are summarized in Table 1.

Also from Fig. 2, the resonators were fabricated on S1, S2, S3 have the high S_{11} values at resonance frequency of 2.9, 3.0, and 2.7 GHz, respectively.

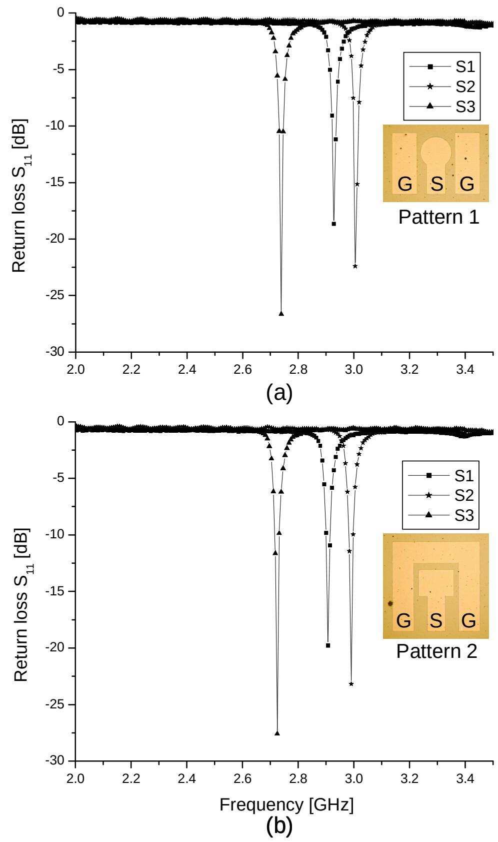

Fig. 1 Return loss characteristics versus frequency for various bottom electrode thicknesses: (a) Pattern 1; (b) Pattern 2.

Table 1 Return loss values of the resonator samples with different patterns

Samples / Patterns	Return loss S_{11} [dB]		
	S1	S2	S3
Pattern 1	-18.64	-22.40	-26.65
Pattern 2	-19.76	-23.18	-27.58

The quality of Bragg reflector seems to significantly influence the FBAR characteristics. In the as-deposited W/SiO_2 multilayered Bragg reflector, there may exist some physical imperfections in the film microstructures and/or some imperfect adhesions at interfaces between the physically deposited films, thus degrading the device performances [4], [5]. By a sputtering deposition, the Cr adhesion layers were inserted to enhance the adhesion between W and SiO_2 layers as well as the uniformity of the thin-films layers deposited for BR fabrication. The fabricated FBAR devices were observed to resonate at 2.7–3.0 GHz with good return loss values. Thus, the FBAR devices appear to be applicable for the 2.7–3.0 GHz broadband WiMAX applications.

The performance of FBAR devices can be determined by the figure of merit (FOM) in terms of Q-factor [6]. Based on the definition reported in [7], the series/parallel resonance Q-factors ($Q_{s/p}$) were calculated and shown in Table 2.

Table 2 $Q_{s/p}$-factors for the resonator samples

Sample	Pattern 1		Pattern 2	
	Q_s	Q_p	Q_s	Q_p
S1	7223	5123	7156	5233
S2	7567	6832	7265	6434
S3	7892	6586	7985	6752

3. Conclusions

A new technique to fabricate the ZnO-based FBAR devices is presented together with device measurements. The FBAR devices were found to resonate at 2.7–3 GHz frequency with good return losses and high Q-factors. This FBAR device fabrication technique seems highly feasible for mobile broadband WiMAX applications.

Acknowledgements

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