Cobalt (Co) Electrode FBAR Devices Fabricated on Seven-Layered Bragg Reflectors and Their Resonance Characteristic

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Abstract

In this paper, cobalt (Co)-electrode FBAR devices fabricated on seven-layered Bragg Reflectors are presented along with their resonance characteristics. ZnO films are used as the resonating material in FBAR devices where the Co electrode is 3000Å thick. All processes are preformed in an RF magnetron sputtering system. As a result of characterization, the resonance characteristics are observed to depend strongly on the quality of ZnO film and Bragg Reflectors. In addition, the FBAR devices with W/SiO_2 reflectors show good resonance characteristics in term of return loss and quality-factor (Q-factor).

I. Introduction

This film bulk acoustic wave resonator (FBAR) or its technology plays an important role in fabrication of the next generation radio-frequency (RF) filters. This is because the FBAR technology can be integrated with the current silicon process technology, eventually enabling the current off -chip type of RF filters to be realized in the type of the microwave monolithic integrated circuits (MMICs) [1, 2]. The FBAR device operation is based on the fact that there is a resonance between the two electrodes due to piezoelectric film when an acoustic wave propagates through this piezoelectric film sandwiched structure between the top and bottom metal electrodes [3]. Accordingly, the piezoelectric property may play a critical role in determining the resonance characteristic of the FBAR devices. The piezoelectric property is determined by the degree of the c-axis preferred orientation of the piezoelectric film. In this paper, we present the characteristics of the ZnO films deposited on Co bottom electrode, the fabrication of FBAR devices on seven-layered Bragg Reflectors. The growth characteristics of the deposited ZnO films are shown to have a strong dependence on the deposition temperature and the portion of oxygen gas. Based on the experimental points, several FBAR devices were fabricated and measured.

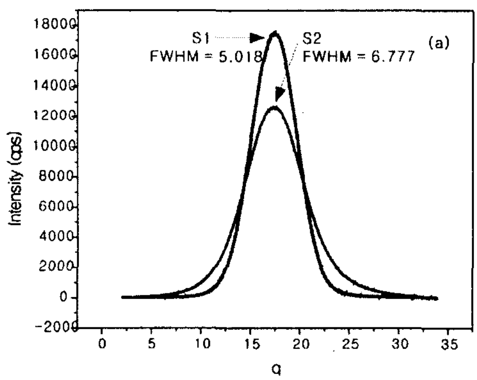
II. Experimental

In this work, the ZnO piezoelectric films were deposited on Si wafer using a RF magnetron sputtering technique with different conditions for investigation of its characteristics. At here, the ZnO films were made with different temperatures (from room temperature to 400℃) as well as various portions of Oxygen in pressure Ar/O_2 gas ratio. The preferred growth characteristics of the ZnO films were analyzed with a Rigaku D/max-RC X-ray diffractometer (XRD) with CuK_α radiation at 30kV and 60mA. The microstructures and preferred crystal planes paralleled to substrates were evaluated by the θ scan method. Beside the ZnO's investigation, the seven-layered Bragg Reflector SiO_2/W was fabricated also by using a RF magnetron sputtering technique. The SiO_2 and W films were deposited on SiO_2/Si wafer 4 inches. The 0.6m thick W films were deposited in medium of Ar gas pressure 15 mTorr, room temperature with DC power 150

Watts; and 0.6m thick SiO_2films were deposited in medium of Ar gas pressure 4 mTorr, room temperature with RF power 300 Watts, successively. Next experiment is to realize a FBAR using the ZnO film with a high quality. The patterning for top Co electrodes formation was defined on the ZnO films by the conventional photolithography technique using AZ1512 photoresist (PR) and pattern masks. Then, the Co films were deposited on the patterned PR layer, followed by the lift-off processing to strip off the remaining PR layers. The top Co electrodes patterning completed the fabrication of the FBAR devices.

III. Results & discussion

Firstly, the effects of the deposition temperature and portion of Oxygen in pressure Ar/O_2gas ratio on the growth characteristics of these ZnO films were performed using XRD method fig. 1. Fig. 1(a) shows the resulting XRD measurements of the ZnO films deposited under various deposition temperatures (23℃ to 400℃). It is clearly certified that the different qualities of ZnO films are shown for different temperature values, as shown in XRD measurements. In the room temperature 230C, the ZnO film sample (named S2) has lower intensity peak (12619 cps) than the sample S1 (17492 cps)- which was fabricated at 4000C. In addition, the FWHM number of S2 sample is smaller than S1 sample. The smaller FWHM number and higher intensity of ZnO film is, the better quality ZnO film is



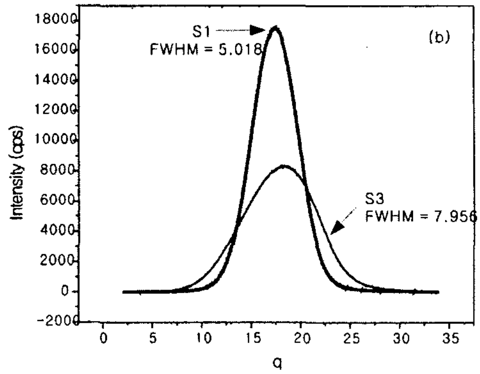


Fig. 1 XRD graph of the ZnO films. (a) Comparison between samples S1 and S2, which were deposited at 400℃ and room temperature, respectively; (b) Comparison between samples S1 and S3 were deposited with Ar/O_2 gas ratios 2:1 and 1:1, respectively.

The other effect factor to the ZnO characteristics is the portion of Oxygen in pressure Ar/O_2 gas ratio during the deposition time of ZnO. In this work, the oxygen concentration seems to strongly effect to the ZnO film quality characteristic. In the fig. 1(b), with the Ar/O_2 gas ratio is 2:1, the ZnO film, named sample S1, has better quality characteristic then ZnO film sample S3, which fabricated in gas ratio 1:1. The sample S1 has higher peak of intensity (17492 cps) and smaller FWMH number (5.018) when compare to the sample S3 - peak of intensity is 17492 cps and FWMH number is 6.777. Because the quality of sample S1 and S2 is nearly the same, thus the ZnO film in our fabrication of resonators was deposited in room temperature.

Secondly, based on the above experimental results, several FBAR devices were fabricated. The top signal and ground electrodes as well as ZnO film were deposited on the top of seven-layered Bragg reflector, as shown in Fig. 2.

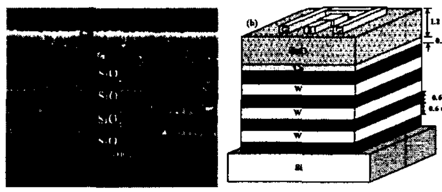


Fig. 2 A cross-sectional schematic of an FBAR structure with ZnO film, Al electrodes and SiO_2/W reflector layers on Si substrate, and a 3-dimensional schematic of the FBAR device with the top electrode pattern.

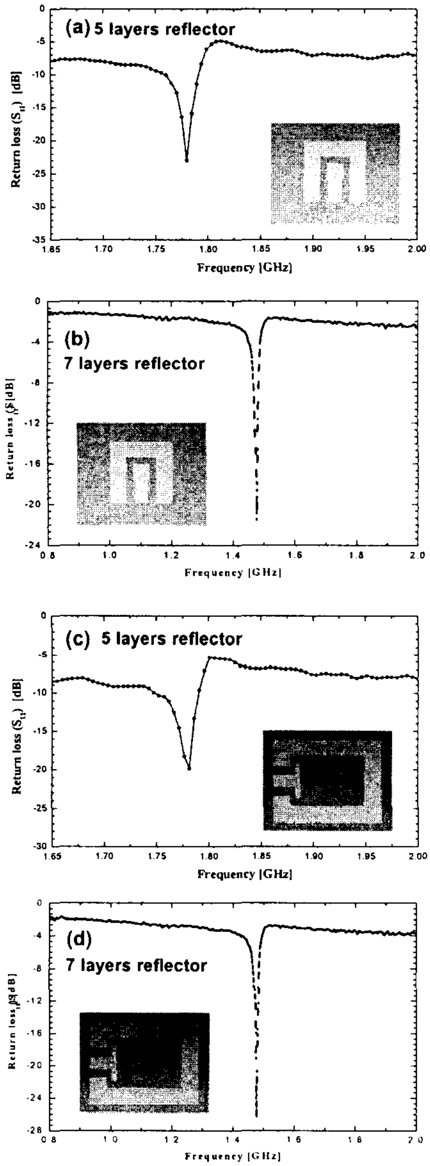


Fig. 3 The comparison return losses S11 between one-port 5-layer reflectors and 7-layer reflectors FBAR devices with the same top-view patterns

After device fabrication, each resonator was measured to extract the S11scattering parameters by using an HP 8722ES network analyzer and a G-S-G probe tip. It is noted that the bottom Co electrode serves as a floating ground. Fig. 3 shows the top-view patterns and return losses of the one-port FBAR devices when compare to the return loss of resonators which were fabricated on 5-layered Bragg reflector [4].

With the same pattern, the 7-layer reflector FBAR devices have higher return loss than the 5-layer reflector FBAR devices. Fig. 4 illustrates results of return loss of some new other patterns. As a result, the Co electrode FBAR devices fabricated on seven-layered reflector show the return loss of around 20 34dB at resonant frequency of ~1.47GHz.

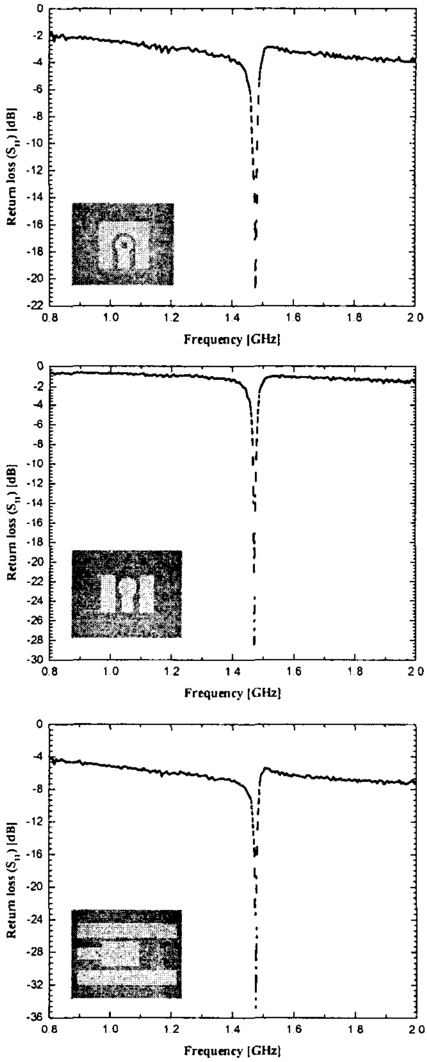


Fig. 4 The top-view patterns and return losses S11 of the one-port FBAR devices with some new patterns.

The resonator performance could be evaluated using the following two figures of merit (FOM), K^2_{eff} and $Q_{s/p}$ [5]. Where, K^2_{eff} and Qs/p determine the maximum attainable bandwidth of filter and resonator loss, respectively [6]. Fig. 5 shows the slope of as a function of the frequency.

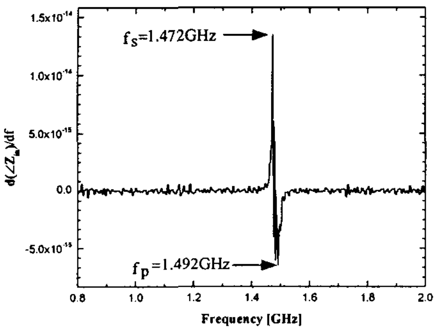


Fig. 5 Slope of as a function of the frequency for the specific resonato

The calculated series and parallel Q-factor values (Q_s and Q_P) and K^2_{eff} for one typical resonator pattern and one from [4] are tabulated in table 1.

Table 1. The summary of thecalculated series and parallel Q-factor values (Q_s and Q_P), and K^2_{eff} for a typical resonator pattern.

fs (GHz)	fp (GHz)	K2eff (%)	Qs	Qp	
1.472	1.492	3.31	9953	4793	This work
1.776	1.799	3.29	2808	2517	[4]

IV. Conclusion

In this paper, the characteristics of the ZnO films deposited on Co bottom electrode and the temperature effects, gas pressure ratio on the ZnO film growth are presented along with the fabrication and their evaluation of FBAR devices. The growth characteristics of the deposited ZnO films are shown to have a strong dependence on the deposition temperature as well as gas pressure ratio. Overall, the ZnO films deposited at room temperature seen to have the same quality as 4000C. Based on the experimental findings, the cobalt-electrode FBAR devices fabricated on seven-layered Bragg Reflectors are show the better return loss results (from 20 to 34dB) at resonant frequency of ~1.47GHz when compare to cobalt-electrode FBAR devices fabricated on five-layered Bragg Reflectors

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