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FBAR using $LiNbO_3$ thin film deposited by CVD
CVD で成膜された $LiNbO_3$ 膜を用いた高周波バルク共振子

Michio Kadota, Yusuke Suzuki and Yoshihiro Ito† (Murata Mfg. Co., Ltd)
門田 道雄，鈴木 雄介，伊藤吉博 (村田製作所)

1. Intordunction

In recent years, high frequency and wider bandwith devices are strongly required, for instance, for mobile phone systems. Film bulk acoustic wave resonator (FBAR) devices using an AlN film have been commercialized[1]. But the AlN film with a small electro-mechanical coupling factor is not suitable for filters requiring wideband. A bulk acoustic wave (BAW) device using a thin single crystal plate of $LiNbO_3$[2] and the lamb wave resonator using a $LiNbO_3$ film deposited by a chemical vapor deposition (CVD)[3] were reported. A FBAR using a $LiNbO_3$ film, which is suitable for high frquency, has not been reported yet. In this paper, authors realized to fabricate a FBAR using a thin $LiNbO_3$ film deposited by the CVD.

2. Device Structure

A FBAR composed of a structure shown in **Fig.1** was fabricated. A buffer layer to fabricate an air-gap-type membrane[3,4] and a bottom electrode was deposited on a base substrate. A $LiNbO_3$ film of about 410nm thickness was deposited on the bottom electrode on the buffer layer by the CVD at a substrate temperature of 650-860℃. After top electrodes were deposited on it, the air gap was made by removing the buffer layer. The sizes of the membrane and the bottom electrode are 200μm squares and 150× 120μm, respectively. The size of the both top electrodes is 50× 120μm and a length between the electrodes is 50μm. The bottom electrode is not to the ground, because it is held on potential float.

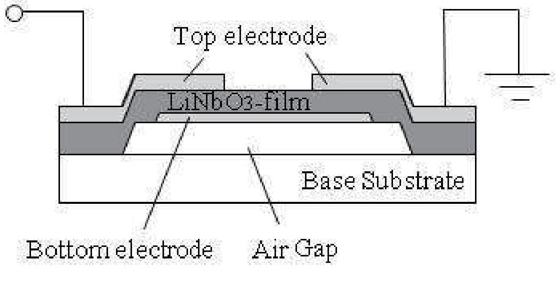


Fig. 1. Device structure : cross sectional view.

3. Properties of $LiNbO_3$ film

A result of the X-ray diffraction measurement shows that the thin $LiNbO_3$ film on the bottom electrode on the buffer layer is a c-axis-oriented film. As a result of the rocking curve measurement, its full width at half maximum (FWHM) is as narrow as about 0.4°. **Fig.2** shows a measured pole figure of the $LiNbO_3$ film at (0, 1, 14) plane. It is considered that the $LiNbO_3$ film is a twinned epitaxial one because six spots exist in the pole figure. Therefore, it is concluded that the $LiNbO_3$ film on the bottom electrode on the buffer layer is the c-axis-oriented twinned epitaxial one.

Figs.3(a) and **3(b)** show an atomic force microscope (AFM) image and a scanning non-linear dielectric microscope (SNDM) image[5], respectively. The surface roughness of the $LiNbO_3$ film shown in Fig.3(a) is as smooth as the RMS roughness is 14.6nm. The SNDM can measure the polarity[5] and the black region and the white region in Fig.3(b) show the +c domain and the –c domain, respectively. As shown in Fig.3(b), the $LiNbO_3$ film has a mixture of the polarity. It is found that -c domains and +c domains occupy 82% and 18%, respectively.

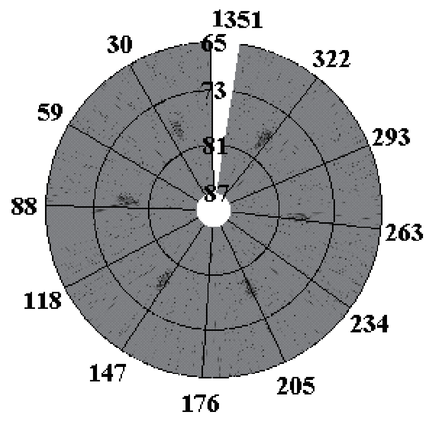
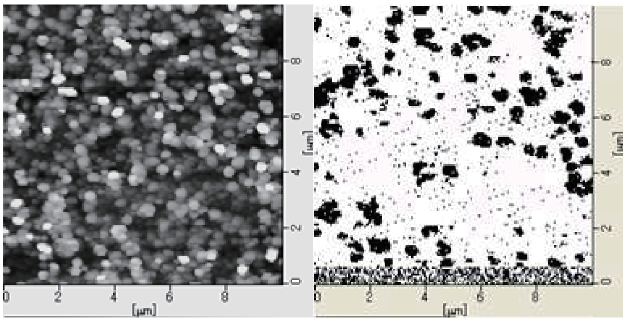


Fig. 2. Pole figure of $LiNbO_3$ film at (0, 1, 14) plane. Six spots are observed.

yitou@murata.co.jp



(a) (b)

Fig. 3. (a) AFM image and (b) SNDM image

4. Impedance Characteristics

Figs.5 and **6** show the measured impedance and phase characteristics of the FBAR using the thin $LiNbO_3$ film. As shown in Fig.6, no spurious responses exist in this range. A resonant (fr) and an antiresonant (fa) frequencies are 2.90133 and 2.97267 GHz, respectively. A relative band width (BW) and an electro-mechanical coupling factor (kt^2) are defined as follows.

$$BW = \frac{fa - fr}{fr} \tag{1}$$

$$kt^2 = \left(\frac{\pi}{2}\right)\cdot\left(\frac{fr}{fa}\right)\cdot \tan\left(\frac{\pi}{2}\cdot\frac{fa - fr}{fr}\right) \tag{2}$$

The BW is 2.5% and kt^2 is 5.8% calculated by those equations. An impedance ratio at the fr and fa is 40dB, quality factor at fr (Qr) is about 73.

A kt^2 of thin plate resonator using c-axis normal AlN is 7.0% and one of c-axis normal $LiNbO_3$ is 2.75%[6]. It is necessary to deposit another oriented $LiNbO_3$ film with larger coupling factor to realize a wider band resonator, for example a inclination of c-axis from vertical is 65° [2,7]. A quality factor is small because it is considered that the film has mixed polarity, the thickness is not flat and the structure of electrode is not optimum.

5. Conclusion

The authors have realized the FBAR using the thin $LiNbO_3$ film deposited by the CVD for the first time. As a result, the resonator showed a 2.9 GHz high resonator frequency, which was higher than the BAW composed of a $LiNbO_3$ single crystal plate, and a large impedance ratio at fr and fa. A quality factor is small because it is considered that the film has mixed polarity, the thickness is not flat and the structure of electrode is not optimum. It is necessary to deposit another oriented $LiNbO_3$ film with larger coupling factor to realize a wider band resonator.

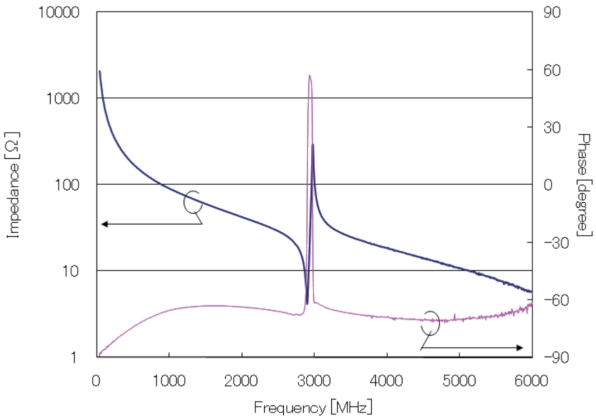


Fig. 5. Measured impedance and phase characteristics (wide range).

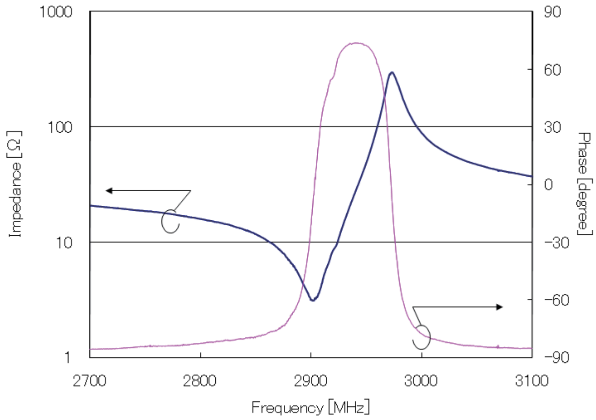


Fig. 6. Measured impedance and phase characteristics around main response (narrow range).

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