2E2-1

Polarity inverted ScAlN films for application to transformer in rectenna

レクテナ用昇圧回路への応用を目指した c 軸ジグザグ配向 ScAlN 多層膜横波共振子

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1. Introduction

Energy harvesting from surrounding electromagnetic wave can satisfy the increasing demand of trillions of wireless sensors for IoT. RF energy harvesting is generally achieved by RF-DC conversion using a rectifying antenna (called rectenna). For weak RF signal, however, RF-DC conversion efficiency significantly decreases because weak RF signal cannot activate the diode in the rectenna. Therefore, in order to obtain high conversion efficiency for a weak signal, a Dickson charge pump [1] is generally used to increase the RF voltage. However, their low efficiency, poor impedance matching, and large size are the problem.

In this study, to overcome this problem, we introduce the RF energy harvester consisting of a new type of polarization inverted FBAR transformer and rectenna. As shown in **Fig. 1**, RF input signal can be increased 11 times when 12 polarization inversion layered FBAR transformer is used. We previously reported various polarization inverted structure such as (0001)/(000-1) ScAlN films [2] and (-1-120)/(11-20) AlN films [3]. We here reports the 12 layer of c-axis zig-zag polarization inverted ScAlN stack transformer resonator.

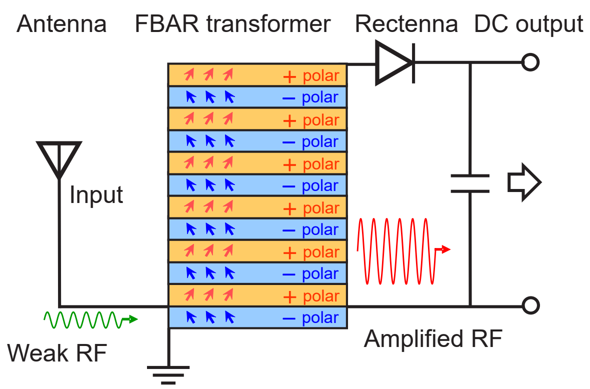

Fig. 1　FBAR transformer rectifying antenna

2. Experiment

c-Axis tilted ScAlN films were grown by a glancing angle magnetron sputtering deposition [4]. After the growth of the first ScAlN film, the substrate was rotated by 180° and the following layers were grown. The c-axis zig-zag structure was obtained by repeating this process.

The magnetron circuit and deposition conditions were optimized to obtain c-axis 45° tilted films. Average deposition rate of each layer was approximately 0.85 μm/hour. The Sc/Al concentration was determined to be 32% by a fluorescent X-ray analyzer.

3. Analysis

Fig. 2 shows the cross-sectional SEM image of ScAlN layers. We can see c-axis zig-zag structure. The thickness of each film was determined to be 3.42 μm. **Fig. 3** shows the (0002) pole figure of 12 layer ScAlN film. Two pole concentrations diffracted from the odd layers and even layers were clearly observed. The pole concentration of even layers was observed at

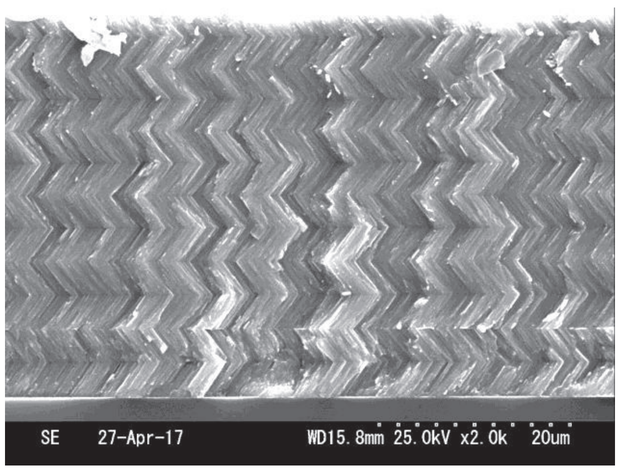

Fig. 2　Cross-sectional SEM image of 12 layer c-axis zig-zag ScAlN film

χ=44.6° and that of odd layers was observed at χ=41.7°. The pole concentration indicates the c-axis tilt dispersion. FWHM values of χ–scan curves of even layers and odd layers were determined to be 10.2° and 12.6°, respectively.

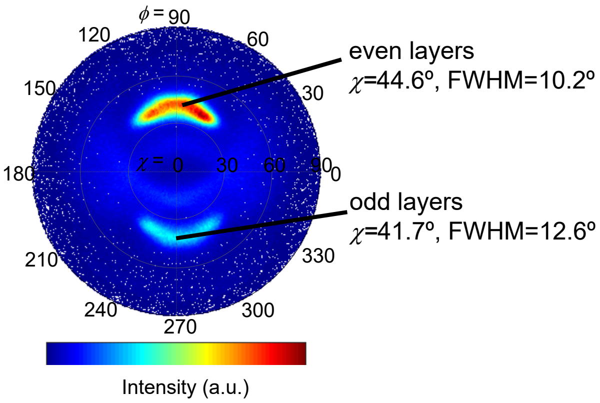

Fig. 3 (0002) pole figure of 12 layer ScAlN film

Fig. 4(a), (b) and (c) show shear wave conversion loss curves of monolayer, 4 layer and 12 layer ScAlN film HBAR consisting of Au electrode/ScAlN film/bottom Al electrode/silica glass substrate. The S_{11} was measured by a network analyzer (E5071C, Agilent Technologies). The time domain impulse response was obtained from an inverse Fourier transform of S_{11}. The first echo from the bottom of substrate was Fourier-transformed into frequency domain to obtain the conversion loss curve.

Monolayer ScAlN film excites fundamental shear mode of 4.0 dB at 492 MHz. Comparing with the experimental and theoretical curves simulated by Mason's model, the $k'_{15}{}^2$ value of the monolayer ScAlN film was determined to be 11.3%.

In contrast, 12 layer zig-zag ScAlN film clearly excites 12th-order shear mode of 1.4 dB at 612 MHz. This experimental curve shows good agreement with the theoretical curve simulated by Mason's model considering twelve polarization inversions.

This new type of polarization inverted FBAR transformer is promising for RF-DC conversion in the rectenna.

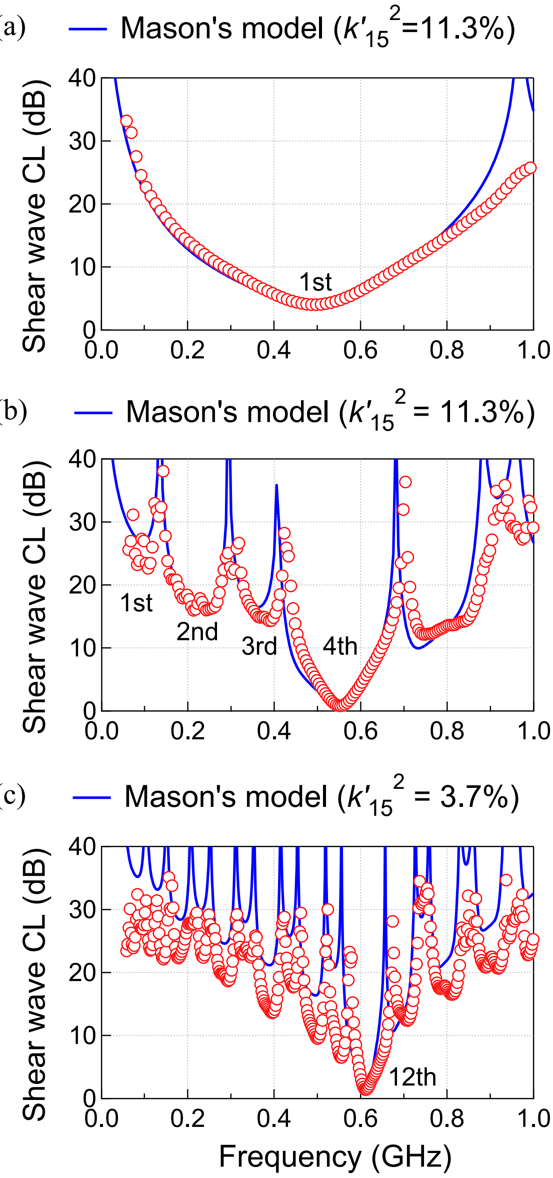

Fig. 4 Experimental and simulated conversion loss of the (a)1 layer (b)4 layer (c)12 layer c-axis zig-zag ScAlN film acoustic resonators

Acknowledgment

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