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1.86 GHz SAW Filter

Toru KASANAMI, Hideharu IEKI and Jun KOIKE

Murata Manufacturing Co., Ltd., Nagaokakyo-shi, Kyoto 617

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Using the third order harmonic wave of Sezawa-mode which propagates in ZnO films epitaxially deposited on R-plane sapphire, high performance filter which is a low insertion loss of 9 dB at 1.86 GHz has been realized.

§1. Introduction

In recent years, a demand for filters of GHz bands has more and more increased in a field of communication equipments and video appliances, in accordance with the recent movement toward even higher frequencies. On the other hand, development of new substrate materials which have high SAW velocity as well as high electromechanical coupling factor, combined with advanced photo-lithography technique for LSI, has enabled the fabrication of SAW filters of GHz bands to become possible in mass production basis.

In such circumstance, using the third order harmonic wave of Sezawa-mode which propagates in ZnO films epitaxially deposited on R-plane $(01\bar{1}2)$ sapphire, we have developed SAW filters which has 1.5–2 GHz center frequency, for the use in a first intermediate frequency stage of double-superheterodyne tuner for TV receivers and CATV converters.

By using the third order harmonic wave of Sezawa-mode, a width of a finger in electrodes becomes larger (about 1 μm at 1.86 GHz) and we can easily fabricate the 1.86 GHz SAW filter. As a result, a low-loss filter, which has an insertion loss of 9 dB at 1.86 GHz center frequency, has been obtained.

§2. Analysis of SAW Properties in ZnO/Sapphire Substrate by Finite-Element Method

Generally, SAW properties have been analysed by solving wave equations, and several studies about SAW properties of ZnO/sapphire substrate with such analyses have been reported.[1] On the other hand, we have employed a finite-element method which can easily incorporate mass-loading effect, and have calcurated h/λ (h: thickness of ZnO films, λ: wavelength) dispersion of phase velocity V_p and electromechanical coupling factor K^2 with respect to SAW which propagates [0001] direction in $(11\bar{2}0)$ ZnO/$(01\bar{1}2)$ sapphire substrate. We think that this wark is the first time of the calculation about ZnO/sapphire SAW properties by a finite-element method. Figs. 1 and 2 show plotted curves of V_p and K^2 as a function of h/λ, respectively. These results show excellent agreement with the solution calculated from the wave equations. The filter was designed by utilizing superior characteristics of $V_p=5500$ m/s and $K^2=0.047$ obtained at $h/\lambda=0.32$. (Sezawa mode)

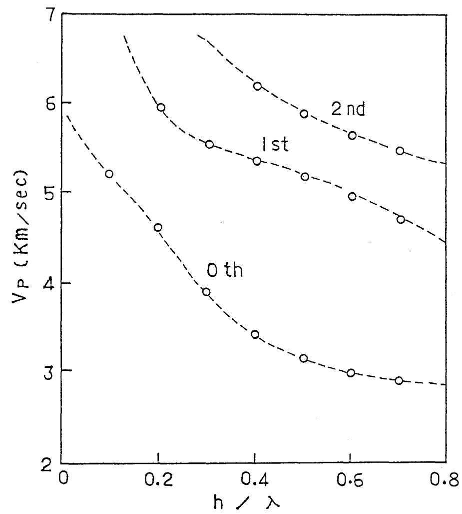

Fig. 1. Plotted curves of V_p as a function of h/λ.

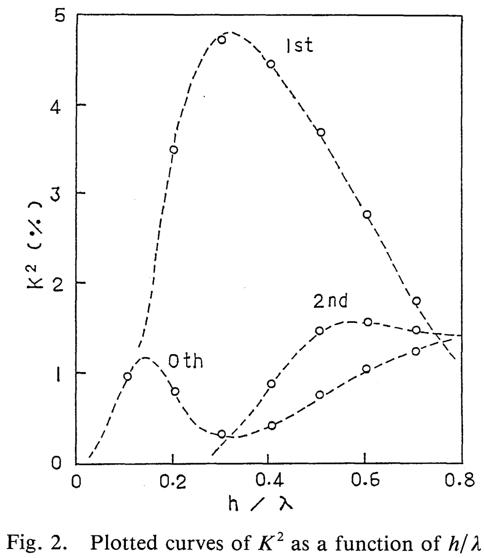

Fig. 2. Plotted curves of K^2 as a function of h/λ.

§3. Preparation and Evaluation of ZnO Epitaxial Films on Sapphire

To deposit ZnO epitaxial films on R-plane sapphire, several methods have been reported so far.[2] Among those methods, we have employed the planar magnetron sputtering, which has been used for VIF SAW filter mass production in our company. This method can deposit films at relatively low temperature with high deposition rate, and the prepared films have a very smooth surface.

Table I. Sputtering conditions.

Target	Zn (metal)
Sputtering gass	O_2:Ar=50:50
Gas pressure	5×10^{-3} Torr
Temperature	200~300°C
RF power	1 kW
Deposition rate	~1 μm/h

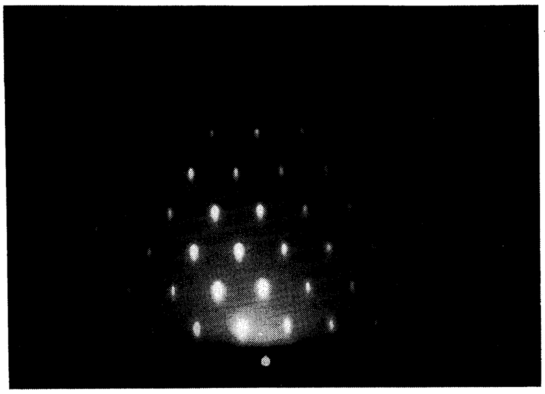

Fig. 3. RHEED Patterns of ZnO films.

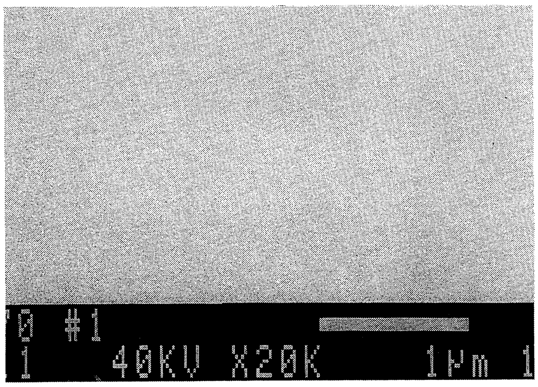

Fig. 4. SEM micrograph of ZnO surface. (×20000)

Planetary motion was used for a fabrication of ZnO films, and so uniform thickness distribution was realized. Table I shows sputtering conditions for the film preparation. Reactive Sputtering was carried out by using a Zn-metal target in O_2 atmosphere. Qualities of the prepared ZnO films were evaluated by using RHEED for crystallographical analysis, and by SEM for analysis of ZnO film surface. These results are shown in Figs. 3 and 4, respectively, which suggest that the ZnO films obtained are epitaxially deposited and have a very smooth surface. In this fabrication of the 1.86 GHz filter, the thickness of ZnO films is 0.9 μm.

§4. Design of Electrode and Manufacturing Process

In designing the filter, great emphasis is placed on the realization of low insertion loss of less than 10 dB in the vicinity of 2 GHz. The three transducer configulation was employed to reduce bidirectional loss. Considering the mass production at the photo-lithography process, split type elctrodes were employed, and with which the third order harmonic waves were generated. Center transducer was apodized (58 pairs), and the other two were unapodized (15 pairs each). The both width of the line and the space in electrodes are 1.05 μm. The propagation length is 550 μm. In photolithographic process, Al electrodes were fabricated by using lift-off technique. Finally the filter was hermetically sealed in a TO-39 package.

§5. Evaluation of Filter characteristics

Electrical characteristics of the 1.86 GHz filter fabricated as above were evaluated. Figs. 5 and 6 show frequency responses of this filter. Measurements were done by using a RF network analyzer which has a 50 Ω system. In Fig. 5, because of coincidence of V_p and K^2, the main peak at 1.86 GHz is the third order harmonic of Sezawa mode, and the other responses at 600 MHz and 1300 MHz correspond to the fundamental response and the third order harmonic of Rayleigh mode, respectively. The fundamental response of Sezawa-mode is not seen, because it becomes mode cut-off and K^2 is very small at $h/\lambda\sim0.1$ as known from Figs.1 and 2. The insertion loss of this filter is 9.5 dB, and then we have had the very low

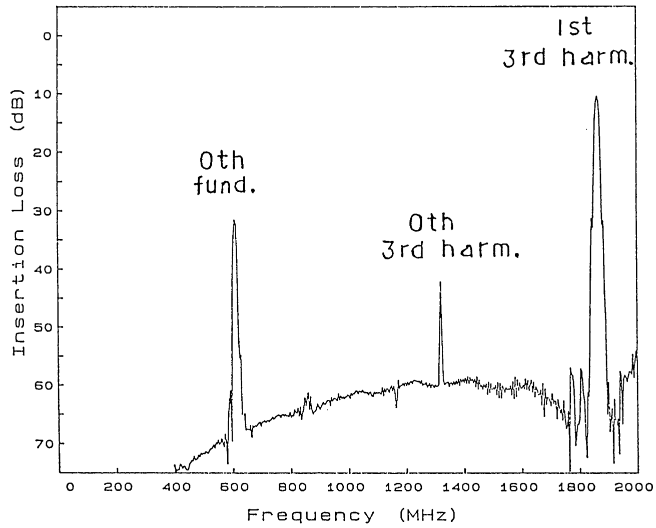

Fig. 5. Frequency response of the 1.86 GHz filter.

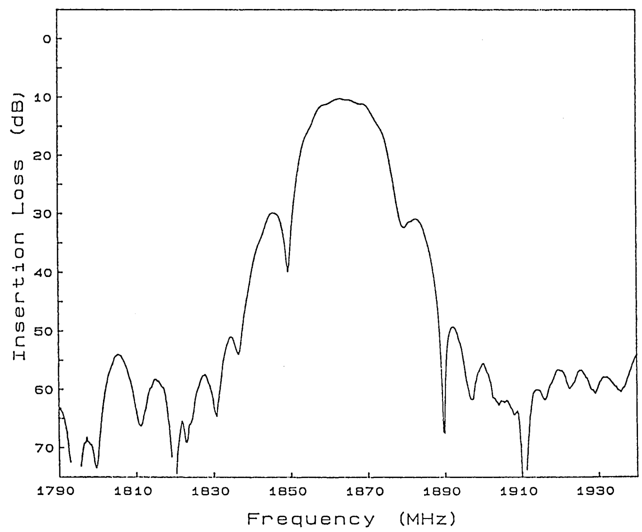

Fig. 6. Overall frequency response of the 1.86 GHz filter.

loss SAW fiters at the high frequency range of near 2 GHz. The estimated causes of this insertion loss are as follows.

Bidirectional loss	3 dB	
Propagation loss	3.9 dB	(70 dB/cm)
Apodization loss	0.9 dB	
Mismatch loss	0.5 dB	
Ohmic loss and Bulk-wave scattering loss	1.2 dB	

Thus, if impedance matching were done, the insertion loss of this filter would be 9 dB.

§6. Conclusion

We have developed 1.86 GHz SAW filter which is designed for the use at first intermediate frequency stage of double superhetelodyne tuner for TV receivers and CATV converters. It employs the third order harmonic wave of Sezawa mode which propagates in ZnO films epitaxially deposited on R-plane sapphire. As a result, high performance filter, which exhibits a low insertion loss of 9 dB at center frequency of 1.86 GHz, has been realized.

Reference

1) T. Mitsuyu, S. Ono and K. Wasa: J. Appl. Phys. **51** (1980) 2464.
2) S. Ohnishi, Y. Hirokawa, T. Shiosaki and A. Kawabata: Jpn. J. Appl. Phys. **17** (1978) 773.