Proceedings of the 2003 IEEE International Frequency Control Symposium and PDA Exhibition
Jointly with the 17th European Frequency and Time Forum

Investigation of SAW and PSAW Propagation in LGS Crystal by Scanning Electron Microscopy Method

S.A. Sakharov[1*], O.A. Buzanov[1], D.V. Roshchupkin[2]

[1]FOMOS Technology Co., 105023 Buzheninova Str. 16, Moscow, Russia
[*]e-mail: sakharov@fomos-t.ru
[2]Institute of Microelectronics Technology, Russian Academy of Sciences, 142432 Chernogolovka, Moscow District, Russia

Abstract-This paper reports the investigation of the SAW and PSAW propagations in X-, Y- and Z-cuts of LGS crystal by scanning electron microscopy method which is very useful for qualitative and quantitative analysis of acoustic radiation wavefields in piezoelectric materials. Using the scanning electron microscopy method we visualized the diffraction patterns in the acoustic beams on the crystal surface and determined the power flow angles for SAW and PSAW.

Keywords: surface acoustic waves; scanning electron microscopy; langasite.

I. INTRODUCTION

Today, the scanning electron microscopy (SEM) is one of the best methods for the observation of surface and bulk acoustic wave propagation in the piezoelectric materials (Refs. 1-8). The SEM in the secondary electron emission mode permits to visualize the distribution of the electric potential on the crystal surface, because the low energy secondary electrons with energy of 1-3 eV are sensitive enough to the electric field, which accompanies the propagation of the surface acoustic waves (SAW) in the piezoelectric materials.

For observation of the SAW propagation it is possible to use two different modes of the SEM method. For the first one, it is possible to use the SEM in the stroboscopic mode with high-frequency modulation of the electron beam with the frequency of traveling SAW. Under these conditions, the electron beam is in phase synchronization with the traveling SAW, and secondary electron emission from the crystal surface is determined by the electric field, that accompanies the propagation of the traveling SAW in the piezoelectric materials (Refs. 1-4). In the second SEM mode, which is more handy (it is not necessary to use special stroboscopic techniques) the high frequency modulation of the low energy secondary electrons is defined by a stationary electrostatic interference field formed above the crystal surface by the interference between the piezoelectric field of the traveling SAW and the component, normal to the crystal surface, of the electromagnetic radiation field of the interdigital transducer (IDT). The electromagnetic and acoustic waves are mutually coherent, since they are excited by the same source (IDT) and with the same frequency. Since the wavelength of the electromagnetic wave is large than the SAW wavelength, the period of the stationary interference field is equal to the SAW wavelength. Under these conditions, the low energy secondary electrons are modulated by the stationary electrostatic interference field (Refs. 6-7). In our investigations to visualize the SAW propagation in the LGS we used the second method.

II. EXPERIMENTAL RESULTS

These experiments have been performed using a JEOL JSM-840 scanning electron microscope. The SAW was rendered visible in a SEM with an accelerating voltage E=1 kV and a probe current $I_0=6\cdot10^{-10}$ A. The use of high accelerating voltage was not possible because it charged the piezoelectric substrate and led to a distortion of the image due to the deflection of electron trajectories.

In our investigations of the SAW propagation in LGS crystal we used different cuts of the LGS crystal (X-, Y- and Z-cuts). To excite the SAW, the interdigital transducers (IDT) were fabricated on the crystal surface by photolithography technique. The IDT has the following parameters: IDT aperture is W=1.2 mm; number of electrode pairs is N=30; SAW wavelength is Λ=28 μm.

Fig. 1 shows the SEM microphotographs of the traveling SAW propagation in the Y-cut of the LGS crystal. The SAW was excited at the resonance excitation frequency of f=78.78 MHz and propagates with SAW velocity of V=2206 m/s. Fig. 1(b) shows the diffraction pattern in the SAW acoustic radiation field and autocollimation of the SAW beam in the Fresnel diffraction zone which is far from the IDT. The diffraction pattern in the acoustic beam is due to SAW diffraction.

Fig. 2 presents the SEM microphotographs of the traveling SAW propagation in the X-cut of the LGS crystal. The SAW was excited at the resonance frequency of f=80.296 MHz and propagates with the

0-7803-7688-9/03/$17.00 © 2003 IEEE

SAW velocity of V=2248 m/s. The SAW propagation in the X-cut of the LGS crystal is characterized by the difference in the direction of the SAW wave direction and the direction of the acoustic energy propagation (power flow vector). It is seen from fig. 2(b) that the power flow angle (the angle between the SAW wave vector and power flow vector) is equal to PFA=8.7°.

Fig. 3 shows the image of the traveling SAW propagation along direction (100) in the Z-cut of the

(a)

(b)

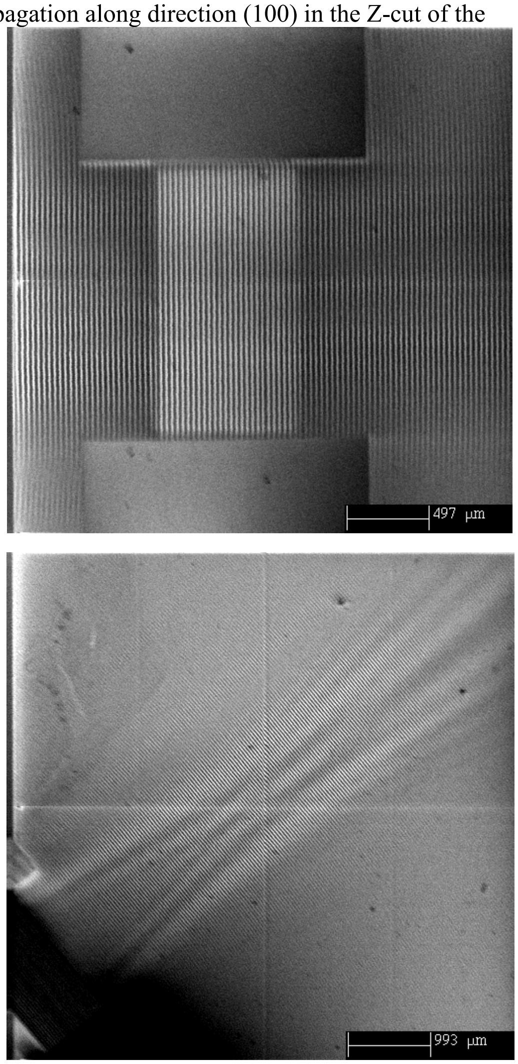

Fig. 1. SEM photomicrographs of the Y-cut of the LGS crystal excited by SAW: (a) – SAW; (b) – diffraction pattern in the acoustic beam. Λ=28 μm; f=78.78 MHz.

LGS crystal excited at the resonance excitation frequency of f=87.236 MHz that corresponds to the SAW velocity of V=2443 m/s. Fig. 4 also presents the SAW propagation in Z-cut of the LGS crystal. But in this case the direction of the SAW propagation is (100)+47°. Fig. 4(a) shows the process of the SAW excitation at the resonance excitation frequency of f=83.793 MHz which corresponds to the SAW velocity of V=2346 m/s. The power flow angle of the SAW propagation in this case is equal to PFA=16.3°. Also using the same IDT it is possible to excite the pseudo SAW. Fig; 4(b) presents the microphotograph of the PSAW excited at the resonance excitation frequency of f=98 MHz. The velocity of the PSAW propagation is equal to V=2744 m/s and power flow angle is equal to PFA=-21.6°.

(a)

(b)

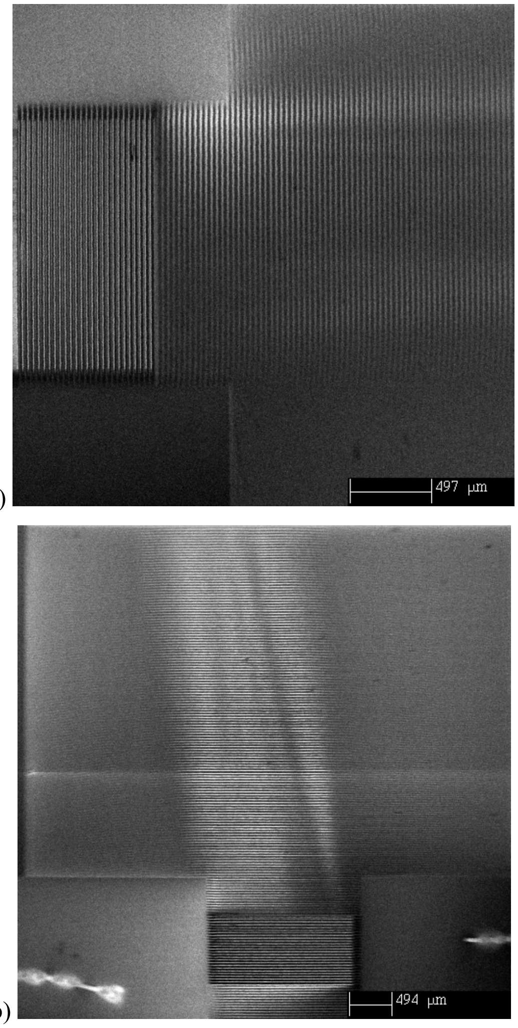

Fig. 2. SEM photomicrographs of the X-cut of the LGS crystal excited by SAW: (a) – SAW; (b) – diffraction pattern in the acoustic beam. Λ=28 μm; f=80.296 MHz; PFA=8.7°.

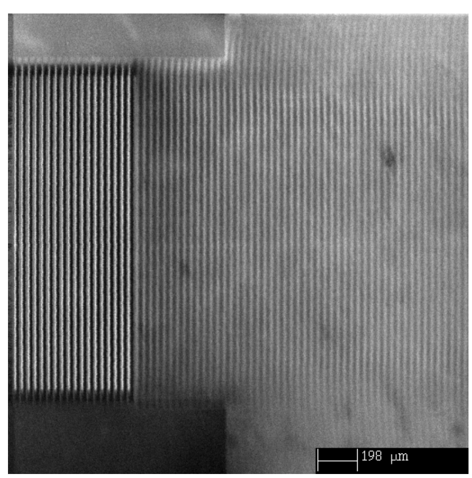

Fig. 3. SEM photomicrograph of the Z-cut of the LGS crystal excited by SAW. Λ=28 µm; *f*=87.236 MHz.

(a) (b)

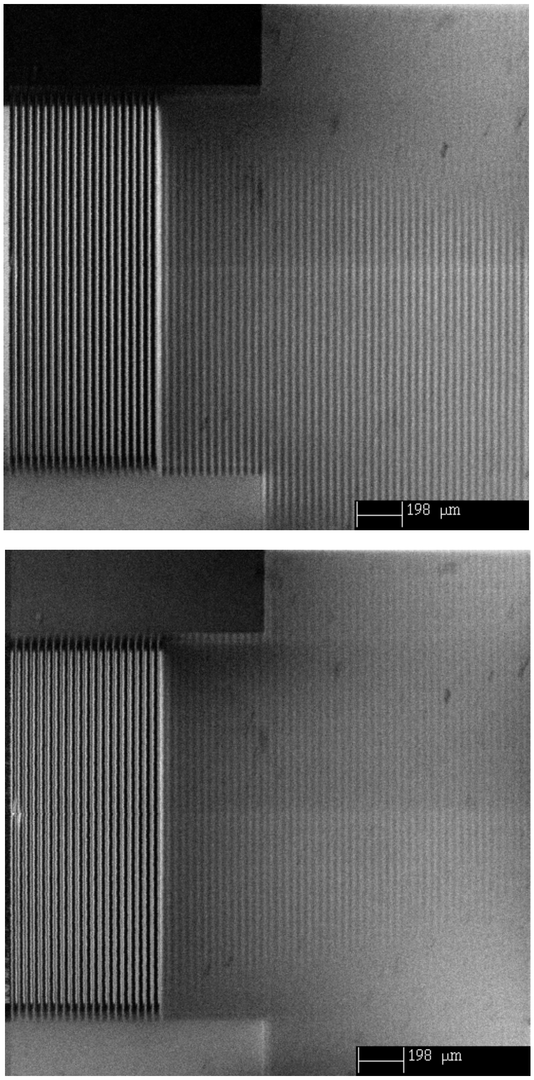

Fig. 4. SEM photomicrographs of the Z-cut of the LGS crystal excited by SAW and PSAW. The SAW and PSAW propagate along the direction of (100)+47°. (a) – SAW; Λ=28 µm; *f*=83.793 MHz; PFA=16.3°. (b) – PSAW;. Λ=28 µm; *f*=98 MHz; PFA=-21.6°.

III. Conclusion

It has been shown that scanning electron microscopy method can be used directly for qualitative and quantitative analysis of the traveling SAW propagation in the LGS crystal. Using this method it is possible to directly visualize the process of the SAW propagation on the crystal surface and to determine the power flow vector.

Acknowledgements

This work has been supported by the Russian Foundation for Basic Research (Contract No. 02-02-22006).

References

1. H. Bahadur, A. Hepworth, V. K. Lall, R. Parshad, *IEEE Trans. Sonics Ultrason.*, vol. SU-25, pp. 309-317, 1978.
2. W. I. Tanski, N. D. Wittels, *Appl. Phys. Lett.*, vol. 34, pp. 537-539, 1979.
3. H. Bahadur, R. Parshad, *Scanning Electron Microscopy*, vol. 1, pp. 509-521, 1980.
4. H. P; Feuerbaum, G. Eberharter, and G. Tobolka, *Scanning Electron Microscopy*, vol. 1, pp. 503-508, 1980.
5. D. V. Roshchupkin, Th. Fournier, M. Brunel, O. A. Plotitsyna, G. Sorokin, *Appl. Phys. Lett.*, vol. 60, pp. 2330-2331, 1992.
6. D. V. Roshchupkin, M. Brunel, *IEEE Trans. Sonics Ultrason.*, vol. 41, pp. 512-517, 1994.
7. D. V. Roshchupkin, M. Brunel, *Acustica.*, vol. 81, pp. 173-176, 1994.
8. D. V. Roshchupkin, M. Brunel, R. Tucoulou, E. Bigler, N. G. Sorokin, *Appl. Phys. Lett.*, vol. 64, pp. 164-165, 1994.