2Pb3-5

Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 221-222
8-10 November, 2011

Optimization of SiO_2 Films and Application of Fluorine Doped SiO_2 Films for Temperature Compensated Surface Acoustic Wave Devices
温度補償 SAW デバイスへ最適化した SiO_2 膜と SiOF 膜の適用

S.Matsuda[1,2‡], M.Hara[1,3], M.Miura[1], T.Matsuda[1], M.Ueda[1], Y.Satoh[1] and K.Hashimoto[2]
([1]Taiyo Yuden Co.,Ltd.; [2]Grad. School Eng., Chiba Univ., [3]Grad. School Eng., Tohoku Univ.)
松田　聡 [1,2‡], 原　基揚 [1,3], 三浦　道雄 [1], 松田　隆志 [1], 上田　政則 [1], 佐藤　良夫 [1], 橋本　研也 [2] ([1]太陽誘電(株),[2]千葉大　工,[3]東北大　工)

1. Introduction

Recently, temperature compensation of surface and bulk acoustic wave (SAW/BAW) technologies has become a topic of interest due to strong demand on wideband filters with excellent temperature stability. Two types of techniques are studied extensively. One is the wafer bonding of a piezoelectric substrate with a support substrate, which have large Young's modulus and small thermal expansion coefficient[1)]. Another one is the deposition of the SiO_2 film on the piezoelectric substrate[2)]. In this type, the TCF improvement is owed to an anomalous property of SiO_2, i.e., SiO_2 becomes stiff with an increase in temperature[3)]. In other words, SiO_2 possesses positive temperature coefficient of elasticity (TCE).

In the latter type, it is known that the TCF (or TCE) considerably depends on the preparation technique and deposition condition of the SiO_2 film [2)]. Nevertheless no systematic investigation has been reported on the relation between the TCE and SiO_2 properties, to the authors' best knowledge. Therefore, a significant amount of try and error is necessary to find the adequate preparation technique and deposition condition even though determined ones may not be optimal.

This paper shows the preparation technique with FT-IR measurement. From this measurement, the optimized SiO_2 films increased the TCF of the device. Furthermore, it can be applied to find the most appropriate dopant for developing high performance temperature compensated SAW devices. As a results, we found that the fluorine doped SiO_2 (SiOF) has larger TCE than that of SiO_2.

2. Experimental Procedure

The TCF of SiO_2 film is represented as the expression below[2)].

$$\mathrm{TCF} = \mathrm{TCV}\text{-}\alpha = \frac{1}{v}\cdot\frac{\partial v}{\partial T} - \alpha \text{、} \quad v = \sqrt{\frac{E}{\rho}} \qquad (1)$$

(v: phase velocity, α: coefficient of linear expansion, E: elastic constant, ρ: density)

From equation (1), we can see that the TCF is

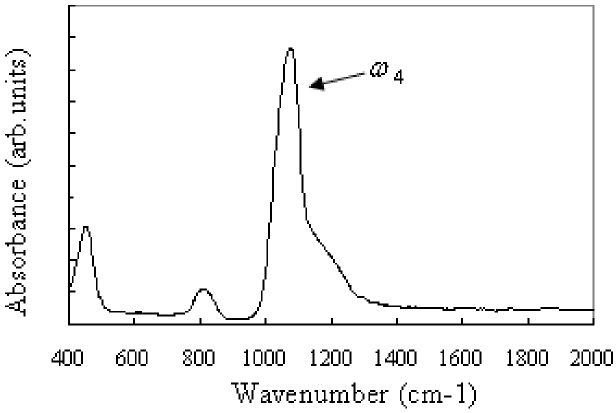

Fig. 1 FT-IR spectra of the deposited SiO_2 films

influenced by TCE (the temperature coefficient of the density variation is less than the elastic constant [2)]).

The SiO_2 or SiOF films with thickness of about 1 μm were deposited on the Si(100) substrate. Then the FT-IR measurement was performed for the wave number between 400 and 2000 cm-1 with a pitch of 1 cm^{-1} (Fig.1). The F content r in the films was measured by the X-ray photoelectron spectroscopy (XPS). The SiO_2 or SiOF films were deposited on SAW devices using 0^{o}YX-$LiNbO_3$ substrate, and their TCF was measured. The thickness of films was set to be 0.3λ.

3. Experimental results

3.1 SiO_2

Figures 2(a) and 2(b) show the TCF as a function of peak frequency ω_4 and FWHM of the peak ω_4 measured by FT-IR, respectively. The TCF increased as ω_4 became larger, and the FWHM became smaller. These results also show optimized SiO_2 film increased the TCF by about 20 ppm/^{o}C in the same thickness, respectively.

We found that the TCE is strongly correlated with behaviors of an absorption peak in the FT-IR spectrum due to vibration modes of the SiO_2 molecular structure[4),5)]. Especially, full width of half maxima (FWHM) of the peak was almost linearly correlated with the TCE with small fluctuation.

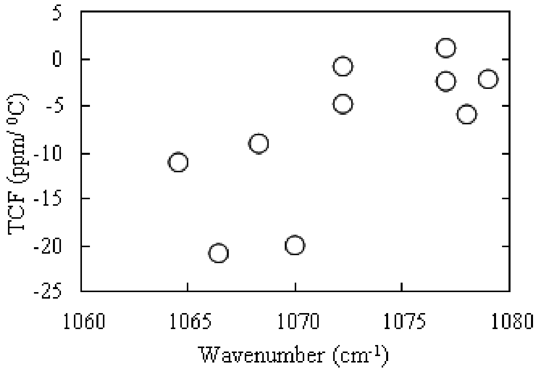

Fig 2(a). Relationship between TCF and ω_4

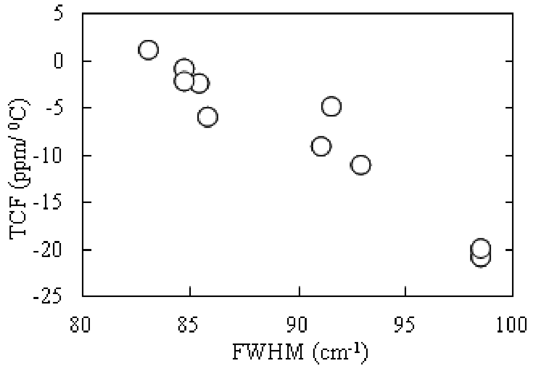

Fig. 2(b) Relationship between TCF and FWHM

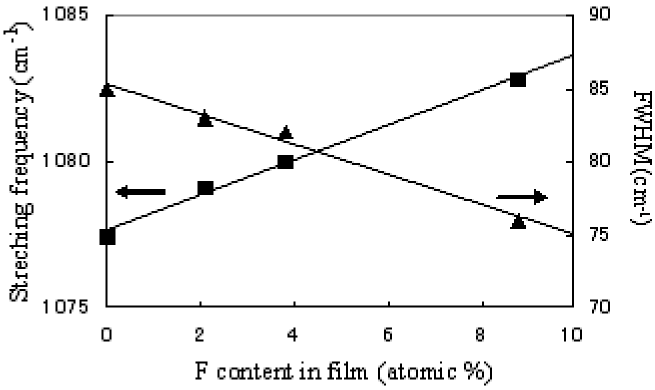

Fig. 3 variation of ω_4 and FWHM with the F content

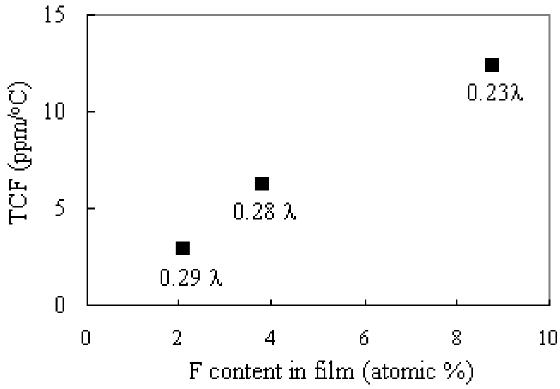

Fig. 4 Change of TCF with F content

This might be explained by the fact that with an increase in FWHM, disorder or non-uniformity of the SiO_2 molecular structure becomes obvious[6], and elastic properties may become non-uniform accordingly.

3.2 SiOF

It was reported that the fluorine doped silicon oxide (SiOF) film possesses higher ω_4 than SiO_2 film[7]. Fig. 3 shows variation of measured ω_4 and FWHM with r. It is seen that SiOF films exhibit higher ω_4 and narrower FWHM than the undoped SiO_2 film, and they change monotonically with *r*. Thus SiOF is expected to offer better TCE than undoped SiO_2.

Next SiOF films with various *r* were deposited on the SAW resonators, and investigated how TCF changes with *r*. Fig. 4 shows the TCF with SiOF. Here *h* was set to 0.29, 0.28 and 0.23λ for *r*=2.1, 3.8, and 8.8 atomic %, respectively, so that measured K^2 is almost equal to that for the SiO_2. It is seen that the TCF increased linearly with *r*, and effectiveness of the F inclusion is confirmed.

4. Conclusion

We investigated the correlation between the TCE and FT-IR absorption spectra of the SiO_2 film for SAW devices. The result indicated that the TCE is strongly correlated with behaviors of an absorption peak frequency in the FT-IR spectrum. Especially, FWHM of the peaks was almost linearly correlated with the TCE with small fluctuation. The measurement also indicated that the optimized SiO_2 films increases the TCF of the device. Furthermore, it was found that the fluorine doped SiO_2 (SiOF) has larger TCE than that of SiO_2 and TCF was increased as the F content increased.

References

1. M. Miura, T. Matsuda, Y. Satoh, M. Ueda, O. Ikata, Y. Ebata and H. Takagi, Proc. IEEE Ultrason. Symp., 2004, p.1322.
2. T. E. Parker and M. B. Schulz, Appl. Phys. Lett. **26** (1975) p.75.
3. K. Hirao, K. Tanaka, S. Furukawa and N. Soga, J. Mater. Sci. Lett. **14** (1995) p.697.
4. P. N. Sen and M. F. Thorp, Phys. Rev. B. **15** (1977) p.4030
5. H. Ogi, T. Shagawa, N. Nakamura, M. Hirao, H. Odaka and N.Kihara, Phys. Rev. B. **78** (2008) p.134204
6. G. Lucovsky, M. J. Manitin, J. K. Srivastava and E. A.Irene, J. Vac. Sci. Technol. B. **5** (1987) p.530.
7. S. Lee and J. W. Park, J. Appl. Phys. **80** (1996) p.5260.