1P3-8

Power Durability Measurement of RF SAW/BAW Devices Considering Their TCF

TCF 特性を考慮した RF SAW/BAW デバイスの耐電力性評価

Luyan Qiu†, Tatsuya Omori, and Ken-ya Hashimoto (Grad. School Eng., Chiba Univ.)
邱　魯岩†，大森　達也，橋本　研也（千葉大院　工）

1. Introduction

High power durability is demanded to RF SAW/BAW devices which are widely used in current telecommunication systems[1]. Power durability is evaluated by time to failure (TTF) and it depends on not only applied power P, chip temperature T but also driving frequency f[2].

At TTF measurement, acceleration with repect to P and T is given to the device under test (DUT), and TTF is estimated from a numerical model established from a series of measurement data.

It is known that the pssband shifts with T due to nonzero TCF. It means the weakest frequency point in terms of TTF changes with T, and thus its effect must be taken into account at the acceleration test.

This paper describes compensation of TCF at the acceleration test of RF SAW/BAW devices. First, it is shown how the filter passband shifts with T, and its numerical model is proposed. Then its impact on the power durability test is presented.

2. Passband Shift and its Modeling

Fig. 1 shows variation of measured insertion-loss of the DUT for WCDMA Band 1 Tx on 42°YX-$LiTaO_3$ (42-LT) with T. In order to shorten the TTF, conventional Al alloy was chosen as an electrode material. The filter passband shifts to lower frequency side with T. It is also seen that the TCF at the upper passband edge is a little larger

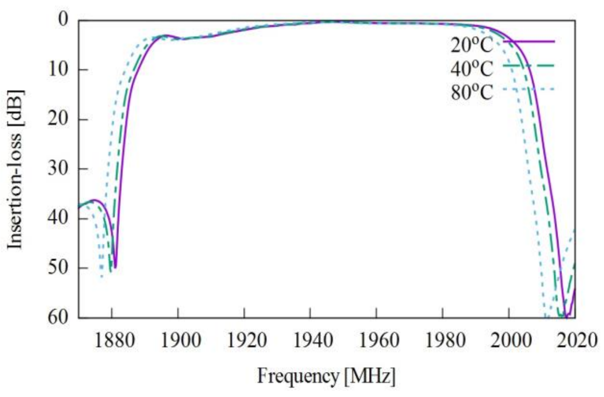

Fig.1 Variation of insertion loss with T. Solid line: 20°C, solid and dotted line 40°C, and dotted line 80°C.

than that at the lower passband edge.

This passband translation is modeled as follows. First, the filter response was measured in various T. Hereafter we denote the measured transfer function at a frequency point f_n and ΔT=T-20°C as $H_{\Delta T}(f_n)$. Then $H_{\Delta T}(f)$ is approximated as $H_{\Delta T}(f_n) \sim H_0(f_n^{'})$ where $f_n^{'} = f_n(1 + a_1\Delta T + a_2\Delta T^2 + a_3\Delta T^3)$, and coefficients a_n (n=1,2,3) are determined by minimization of the following goal function S:

$$S = \sum_n \left| H_{\Delta T}(f_n) - H_0(f_n^{'}) \right|^2 . \quad (1)$$

The range of summation in Eq. (1) is limited between upper and lower corners of the passband. The optimization was performed by the simulated annealing algorithm.

Since $f_n^{'}$ deviates from f_n, $H_0(f_n^{'})$ is estimated by interpolation from the values at two adjacent frequency points f_m and f_{m+1}., namely

$$H_0(f_n^{'}) = H_0(f_{m+1})\frac{f_n^{'} - f_m}{f_{m+1} - f_m} + H_0(f_m)\frac{f_{m+1} - f_n^{'}}{f_{m+1} - f_m} \quad (2)$$

Although not shown, the proposed model can express the passband translation very well.

Fig. 2 shows variation of the estimated TCF. Here the frequency dependent TCF is estimated from the following equation:

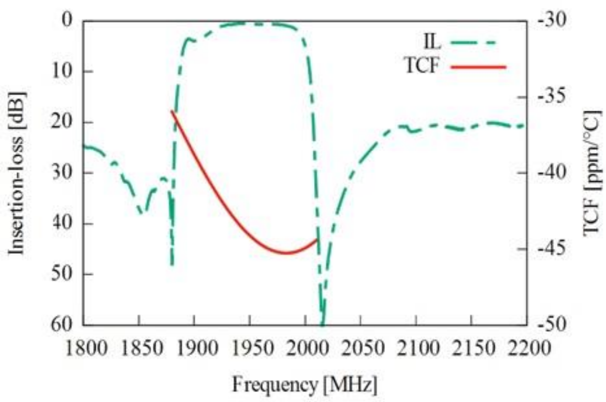

Fig.2 Estimated frequency dependent TCF

$$\mathrm{TCF} = f^{-1}\left.\frac{df}{dT}\right|_{T=20^{\circ}\mathrm{C}} \quad (3)$$

It is seen that the TCF varies rapidly in the

----
keew@chiba-u.jp

passband. Values near the lower passband edge are close to the TCF at the resonance of SAW resonators on 42-LT while those near the higher passband edge are close to the TCF at the anti-resonance.

3. Measurement of TTF

It is known that TTF is well expressed by the following model [2]

$$\mathrm{TTF} = \alpha P^{\beta} \exp\left(\frac{E}{kT}\right) \quad (4)$$

where k and E are the Boltzmann constant and activation energy, respectively. Constants α and β shall be determined from the measurement data. Taking logarithm of Eq. (4) results in the following form:

$$\log_e \mathrm{TTF} = \log_e \alpha + \beta \log_e P + \frac{E}{kT} \quad (5)$$

This means $\log_e$TTF changes linearly with $\log_e P$, and β can be determined from the gradient.

TTF of the DUT was measured using the wafer-probe setup described in [3]. In the case, temperature of the DUT surface is almost equal to that of Cu plate placed under the DUT.

Fig. 3 shows variation of $\log_e$TTF with $\log_e P$ at the room temperature. As expected, $\log_e$TTF changes linearly with $\log_e P$, and β is estimated as -1.59 from the least square fitting.

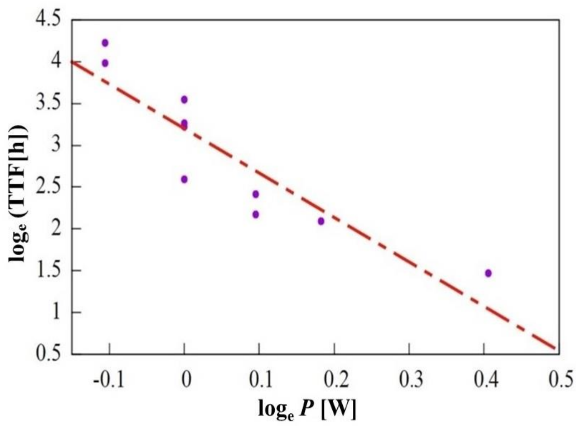

Fig. 3 Dependence of input power to TTF

Fig. 4 shows variation of $\log_e$TTF with T^{-1} when the input RF power is fixed at 1 W. Two curves are given. One is the result when the frequency is fixed at 1,820 MHz (upper bound of Band 1Rx), and another one is the result when the frequency starts from 1,820 MHz at T=20°C and is adjusted according to the model described above. Although $\log_e$(TTF) changes linearly with T^{-1} for both cases, the gradient is significantly different.

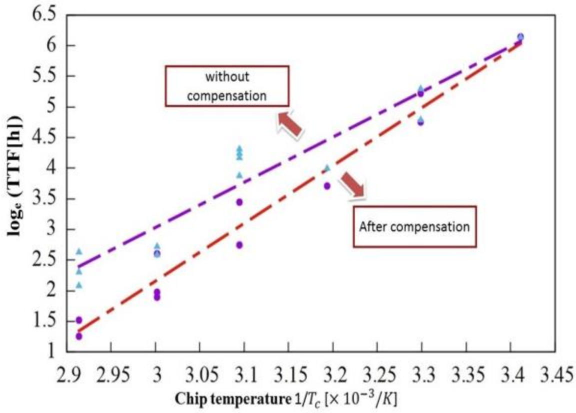

Fig. 4 Variation of TTF with T

From the gradient, E was estimated as 0.636 eV without the TCF compensation while it increased to 0.813 eV with the TCF compensation. Thus, it is clear that impact of the TCF is significant for TTF, and it must be taken into account for the power durability measurement.

It should be noted that the frequency was adjusted following to the frequency response at T=20°C in this experiment, this reference temperature should be set at the chip temperature T_c at the maximum operation temperature T_m given as specification. Since T_c is somewhat different from environmental temperature, the difference must be also taken into account at the TTF measurement[3].

4. Conclusion

This paper described a procedure to estimate the frequency dependent TCF of RF SAW/BAW deices for its compensation method during TTF measurement.

Since excess T results in further translation of the passband, the translation must be compensated by shifting the frequency

Acknowledgements

The authors thank Dr. M. Ueda of TAIYO YUDEN Co., LTD. for supplying the SAW filters used in this work. We also thank members of the Technical Committee No. 49 on Frequency Control Devices, the International Standard Commission (IEC) for their fruitful discussions.

References

1. K.Hashimoto, Proc. IEEE European Frequency and Time Forum (2016) 10.1109/EFTF.2016.7477761
2. R.Takayama, et al., Proc. IEEE Ultrason Symp (2014) p.886
3. T.Omori et al., Proc. IEEE Ultrason Symp (2015) 10.1109/ULTSYM.2015.0090