

# THE STUDY OF AGING FREQUENCY DRIFT MECHANISM FOR QUARTZ CRYSTAL RESONATORS

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Aging as long-term stability is one of the most important characteristics of quartz crystal resonators, and stress and out-gas make major contributions. In this paper, aging frequency drift mechanisms under different conditions of mounting types and aging temperatures are analyzed. The results show that the frequency drift under 85°C aging of both two-point and four-point mounted quartz chip are similar; however, the stability performance under 150°C aging of two-point mounted resonator is much better than that of four-point mounted ones. The main reason is the aging curve of two-point mounted resonator is a compositive aging curve, since effects of out-gas and stress are balanced well, which is supported by the IVA test.

**Keywords:** Aging; Frequency drift; Stress; Out-gas; Mounting type

## 1. INTRODUCTION

With widely application of quartz crystal resonators (X'tal resonators) in mobile phones and automobiles and even accompany with size miniaturization, long-term frequency stability of quartz crystal resonators is identified as the most important characteristic, which has been studied for decades. Aging is generally defined as the time function of frequency drift, which could be affected by many factors, such as stress, out-gas escaping from package and conductive adhesive, contaminations, quartz defect. Especially stress relief and contamination are recognized as most significant, which were analyzed by Gehrke and Klawitter [1]. For X'tal resonators, 2ppm to 5ppm per year at 25°C in commercial applications and 3ppm per year at 25°C in automobiles are usually used for specifications. Therefore many related topics were studied, for instance, effect of geometric variations of the mounting points on aging [2] and experimental results on aging of AT-cut resonators. Hereinto, three typical aging types are presented in the study of J. R. Vig and T. R. Meeker's [3]: positive aging dominated by stress, negative aging dominated by mass loading effect, and compositive aging dominated by both stress and mass loading effect. Nowadays, stress could not be directly detected by using valid methods or equipments, but out-gas could be gauged by Internal Vapor Analysis (IVA test) that could help make sure how out-gas affect aging.

Figure 1 shows a frequency drift tendency at 150°C

of TXC 3.2mm×2.5mm Seam type X'tal resonators that have four mounting points as common, which deviations approach 4ppm after 500 hours.

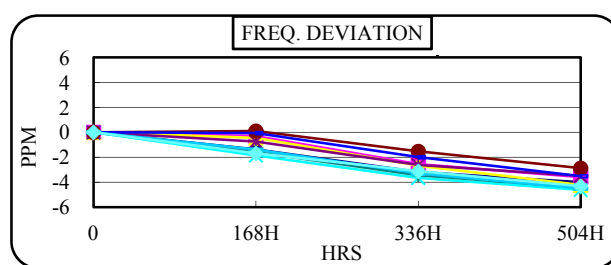


Figure 1. Common frequency drift tendency at 150°C

Negative aging as above is usually seen, that is frequency drift down continually, of which cause was commonly thought as out-gas from conductive adhesive. Theoretically, frequency will be stable when positive effect of stress is equal to negative effect of out-gas, in other words, positive effect will reveal when weakening mass loading effect so that frequency drift will be dominated by stress. In this paper, aging frequency drift mechanism of different mounting types under different aging temperatures will be studied.

## 2. EXPERIMENTS AND RESULTS

### 2.1. Experiments

In our study, TXC 3.2mm×2.5mm Seam type X'tal resonators which frequency is fundamental AT-cut 40

MHz used in experiment, in which silicone-based conductive adhesive that is relatively soft ( $\tan \delta \sim 0.2$ ) and normal production process are used, in addition, the mounting position of conductive adhesive is located as illustration of Fig. 2 to Fig. 4, and the mounting diameter was all controlled as  $250\mu\text{m}$ . A getter resin is ultra adding in experiment to absorb out-gas then reduce mass loading effect, which functions are as an irreversible moisture getter absorbing  $\text{CO}_2$  and  $\text{H}_2\text{O}$ . Setting materials and parameters as above could objectively reflect the aging behavior of different mounting types.

In order to prove what is frequency drift mechanism, two mounting types and two temperatures are used in aging test, and frequency deviation and frequency drift tendencies of two kinds of mounting types are measured and analyzed. Experimental conditions are list in Table 1. There are 6 experiments totally, and 30 samples of each experiment are measured. The average data will be used to get frequency drift tendency.

Table 1. Experimental conditions

Mounting Type	Aging Temperature
2 mounting points with getter	85°C/150°C
2 mounting points	85°C/150°C
4 mounting points	85°C/150°C

Figure 2, Fig.3 and Fig.4 show samples' photos, including front views and side views. Front views are got by optical microscopy and side views are captured by Dandong Aolong X-ray instrument. It is obvious that Fig.2 (a) and Fig.3 (a) are almost same, because getter is just mounted under the blank as Fig.2 (b) so that it cannot be seen from front view.

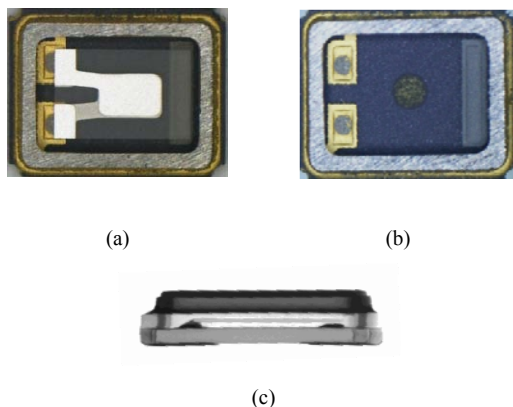


Figure 2. Front view and side view of two mounting points with getter  
(a) Front view; (b) Front view of getter; (c) Side view.

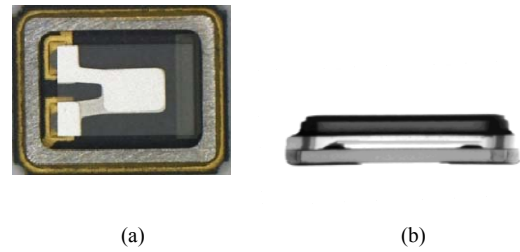


Figure 3. Front view and side view of two mounting points  
(a) Front view; (b) Side view.

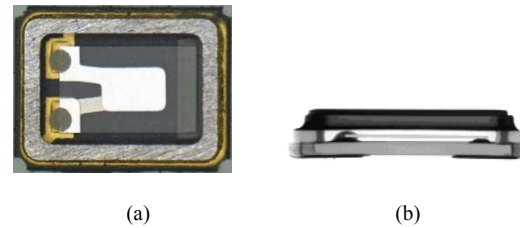


Figure 4. Front view and side view of four mounting points  
(a) Front view; (b) Side view.

In this paper, effects of different experimental conditions on aging will be compared and analyzed, and accompanied with IVA test results by using ORS (ONEIDA RESEARCH SERVICES, INC.) instruments.

## 2.2 Aging Results

By comparative experiments, the results show that frequencies drift are similar under three mounting types at 85°C that are shown in Fig.5, of which frequency deviations after 500 hours are within 2ppm. Figure 6 shows that frequency deviations with different mounting types at 150°C are different, among which frequency deviation with four mounting points after 500 hours reaches nearly 5ppm and frequency deviations with two mounting points are still within 2ppm. Especially the frequency shifts of adding getter in 85°C and 150°C aging show no difference with two mounting points.

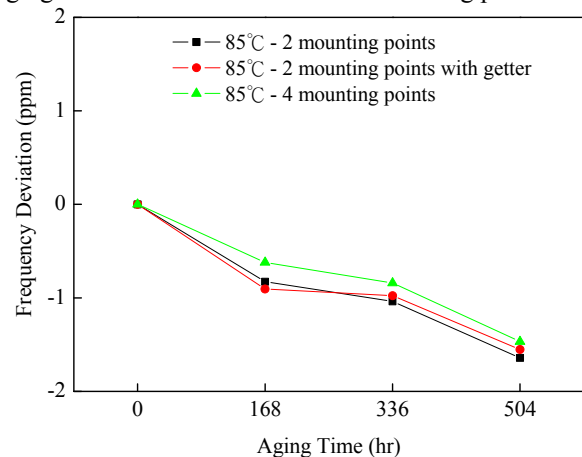


Figure 5. Aging frequency drift tendency at 85°C

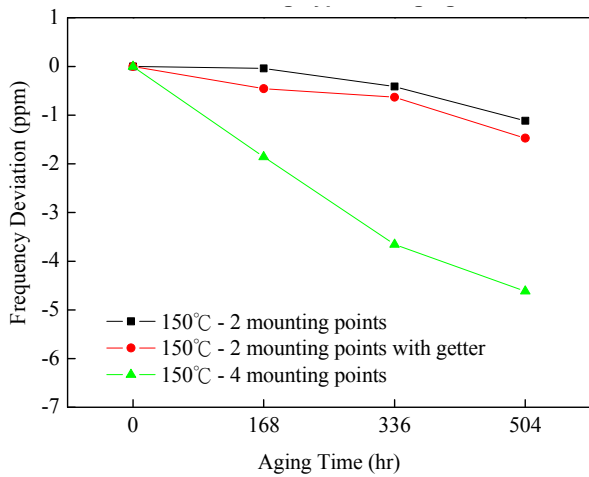


Figure 6. Aging frequency drift tendency at 150°C

In this paper, both stress and out-gas are considered to be existed and affect aging stability together in X'tal resonators. From the results of 85°C aging, it can be inferred that little out-gas escapes from different mounting types so that there is no obvious difference of mass loading effect, therefore, frequency stabilities are similar. When temperature rises to 150°C, more out-gas escaping from four mounting points causes severe effect, so that it is apt to negative aging which frequency drifts down seriously. In contrast, X'tal resonators with two mounting points reduce mass loading effect by getting rid of mounting adhesive upon blank and make stress' positive effect play a leading role in aging, so that its frequency is relatively stable and aging curve tends to compositive aging. Why the aging behaviors of adding getter perform like those of two mounting points, which could be inferred IVA test results.

### 2.3 IVA Results

IVA test is a kind of material out-gassing characterization analysis method and widely used in hermetic devices, which measures the relative volumetric concentrations of volatile organics and other substances in the vapor state. IVA test can only provide the contents relative volume ratio and its accuracy is into ppm scale. Further, assume that the 3.2mm×2.5mm X'tal resonators have the same hermetic volume and are welded in vacuum environment, then the relative volume ration could be transformed into relative mass ratio for analyzing mass loading effect.

In fact all kinds of materials that used in X'tal resonators can degas and might also affect the long term frequency stability, for instance, N<sub>2</sub>, H<sub>2</sub>, H<sub>2</sub>O, and CO<sub>2</sub> can be degassed from ceramic package, metal lid and conductive adhesive. In this paper, the IVA contents are assumed contributed by conductive adhesive since it has

huge parts of composition was organic resin. Table 2 shows the sample state for IVA test.

Table 3 shows IVA result of aging 85°C, from which it can be inferred that CO<sub>2</sub> plays an important role more than H<sub>2</sub> in mass loading effect. And it is seen that there is little difference of relative mass ratio of CO<sub>2</sub> between two and four mounting points, which may be the reason why aging stabilities at 85°C are almost same between two and four mounting points.

Table 4 shows IVA result of aging 150°C. It shows the relative mass ratio of CO<sub>2</sub> in two mounting points is greater than four, which is opposite to the aging performance at 150°C, consequently, it can be inferred that stress is playing a leading role than out-gas.

Table 2. Samples for IVA test

Sample ID	2 mounting points	4 mounting points	2 mounting points with getter
Aging 85°C	#25	#04	#46
Aging 150°C	#35	#14	#56

Table 3. IVA result of aging 85°C

Sample ID		Volume ratio		Mass ratio	
		#25	#04	#25	#04
Ion source pressure	torr	1.1E-7	1.1E-7	1.1E-7	1.1E-7
Nitrogen	%	22.8	16.7	16.0	11.0
Oxygen	%	ND	ND	ND	ND
Argon	%	0.20	0.24	0.00	0.00
Carbon dioxide	%	76.1	82.9	84.0	89.0
Moisture	%	ND	ND	ND	ND
Hydrogen	%	0.90	0.15	0.00	0.00
Methane	%	ND	ND	ND	ND

Comment: ND=None Detected

Table 4. IVA result of aging 150°C

Sample ID		Volume ratio		Mass ratio	
		#35	#14	#35	#14
Ion source pressure	torr	1.7E-7	2.1E-7	1.7E-7	2.1E-7
Nitrogen	%	5.29	32.0	3.00	23.0
Oxygen	%	ND	ND	ND	ND
Argon	%	0.26	0.00	0.00	0.00
Carbon dioxide	%	93.3	68.0	97.0	77.0
Moisture	%	ND	ND	ND	ND
Hydrogen	%	1.15	ND	0.00	ND
Methane	%	ND	ND	ND	ND

Table 5 shows IVA result of two mounting points with getter. The classic methanogenesis (CO<sub>2</sub>+4H<sub>2</sub>=>CH<sub>4</sub>+2H<sub>2</sub>O, which must be in the atmosphere of leak O<sub>2</sub> or burning) happens when adding

getter. And it can prove that the getter really has the function to absorb CO<sub>2</sub>. For adding getter type, N<sub>2</sub>, H<sub>2</sub>O and CH<sub>4</sub> become the main mass loading source, but those molecular weight is far below CO<sub>2</sub>, this is why aging behaviors of two mounting points with getter at 85°C and 150°C are very close to two mounting types which belong to stress controlled.

Table 5. IVA result of two mounting points with getter

Sample ID		Volume ratio	
		#46	#56
Ion source pressure	torr	3.8E-8	4.3E-8
Nitrogen	%	49.3	50.7
Oxygen	%	ND	ND
Argon	%	0.62	0.85
Carbon dioxide	%	ND	ND
Moisture	%	18.7	4.11
Hydrogen	%	5.68	3.84
Methane	%	25.7	40.5

### 3. CONCLUSION

In this paper, we studied the frequency drift behaviors under different mounting designs. Comparing with the four mounting points, the frequency drift tendency of two mounting points is close to compositive aging. The IVA result of two mounting points shows biggest out-gas escapes in 150°C aging that forming negative effect by mass loading, but two mounting points with strong stress controlled positive effect than mass loading, therefore, high frequency stability can controlled small than 2ppm after 150°C aging. Contrariouly four mounting points since CO<sub>2</sub> dominates the negative effect of mass loading is greater than positive effect of stress, consequently, the frequency drift frequency drifts down continuously when aging beginning.

In this paper, frequency deviation of TXC 3.2mm×2.5mm Seam type X'tal resonator through two mounting points stress control, which aging ability at 85°C is the same as four mounting points and satisfy widely commercial applications, for further it could reach 150°C automobile application require even without adding getter to save material cost.

### REFERENCES

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