Some Experiment Results of TCXO Based on Stress Processing

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***Abstract*—We combine the different characteristics of quartz crystal including frequency – temperature characteristics and frequency – stress characteristics, with the influence of stress on the frequency of crystal blank to compensate the temperature influence on the frequency of crystal. A lot of experiments have been done to prove that with stress processing the frequency – temperature performance of overtone crystals can be improved obviously. With this way, the new crystal oscillators can show a good frequency – temperature performance, lower power consumption, lower phase noise and better short-term stability. Now the frequency – temperature stability of the oscillator samples can be better than $\pm$ 1.5ppm from –40 to +80 deg. C.**

To generate the suitable stress, we plate a metal film on the crystal blank to form a temperature – stress sensor based on the different characteristics of quartz and the metal. When temperature changes, there is a possibility for the shape of sensor to be changed also. Therefore, it can apply the stress to the blank of the crystal. We choose overtone crystal and it can show better stability and aging than those of fundamental crystal, and higher frequency – stress sensitivity. The experiments also show that the different metal film shape and position on the blank will generate the different results.

I. INTRODUCTION

Most conventional temperature compensated crystal oscillators use fundamental frequency crystals and the circuit compensation. The phase noise, short-term stability and aging are not very good. Because of the poor frequency regulation range of overtone crystals, they are not suitable for circuit compensation. Compared to fundamental crystals, overtone crystals can show better stability and aging. When it is imposed a stress, the frequency variation is greater than that of fundamental crystals [1]. So, we use the influence of stress on the frequency of crystal to compensate the temperature influence on the frequency of crystal, if this is realized, effect will be better than most of the temperature compensated crystal oscillators at present.

The crystal of a temperature compensated crystal oscillator based on stress processing has the ability of sensor to the outer influences besides the function of frequency stabilization. So we can use the sensing function to compensate the temperature influence on the frequency. In order to generate a stress changing with the temperature on the crystal blank, we plate a metal film on it. The effect will be more obvious if the compensation film is at the edge of the crystal blank. Because the performances of the metal film and the crystal like expansion and contraction coefficient are very different, so when the temperature changes, they will show the trend of deformation as the bimetallic strip. The trend can impose a stress on the crystal blank. So, it is a stress changing with the temperature. Because the curve of the frequency – temperature characteristics is a cubic curve, so the stress curve should be the contrary to the cubic curve. But the change of the stress with the temperature is monotonic. So the frequency – temperature characteristic of the chosen crystal should show the contrary characteristic. Suitable amount of frequency modulation of the compensation film is very important to the compensation effect.

II. EXPERIMENTS AND RESULTS

The performance of the stress compensation crystal oscillators is mostly affected by the original frequency – temperature characteristic, the shape of the compensation film and the amount of frequency modulation corresponding to its thickness. It is introduced in our several patents [2] [3].

Conventional plating materials of crystal oscillators like gold, silver and aluminum and so on are all taken into account in typical temperature compensation film.

The frequency - temperature characteristic of the stress compensation crystal before and after compensation film is plated is shown in Fig.1.

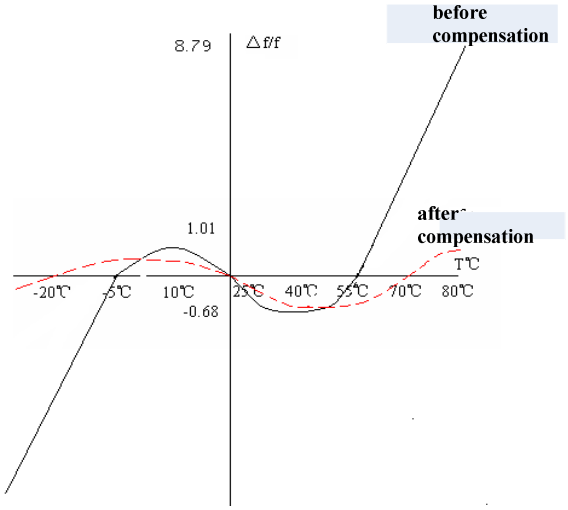

Figure 1. The frequency - temperature characteristics before and after compensation

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Best compensation effect is obtained when the original frequency – temperature performance, the shape of the compensation film and the amount of the frequency modulation corresponding to its thickness are combined suitably. The almost ±1ppm frequency – temperature characteristic can be obtained from –40 to +80 deg. C temperature range.

The key is that this type of oscillators is based on the overtone crystals different from conventional TCXOs based on the fundamental crystals. So, its several main characteristics such as frequency stability, phase noise and aging are all better than common TCXOs.

For the two types of TCXOs that use the same oscillating circuit SM5021ACH, we compare their performances such as frequency stability, phase noise and aging rate between common TCXO and STCXO based on stress compensation. The two oscillators are of the 20MHz frequency. The results are shown in Table.1, Fig. 2, Fig. 3 and Table. 2.

TABLE I. FREQUENCY STABILITIES PER SECOND OF THE TWO TCXO (20MHz)

	TCXO	STCXO
Frequency Stability	6.5×10^{-9}/s	2.1×10^{-9}/s

TABLE II. THE AGING OF THE TWO TCXOS

	TCXO	STCXO
Aging/day	2.4×10^{-8}	6.8×10^{-9}

Fig.2 and Fig.3 show the phase noise of the two types of TCXOs.

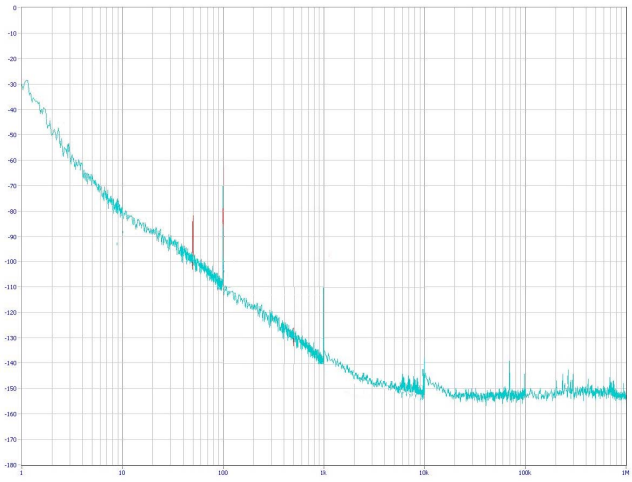

Figure 2. The phase noise of a 20MHz TCXO

From the measurement results, the aging and frequency stability of the STCXO are all about 3 times better than that of TCXO; the phase noise of the STCXO is about 10 to 15dBc lower than TCXO at the condition of near carrier frequency, and the ground noise is 5dBc lower. These are the advantages of the STCXOs besides the temperature performance.

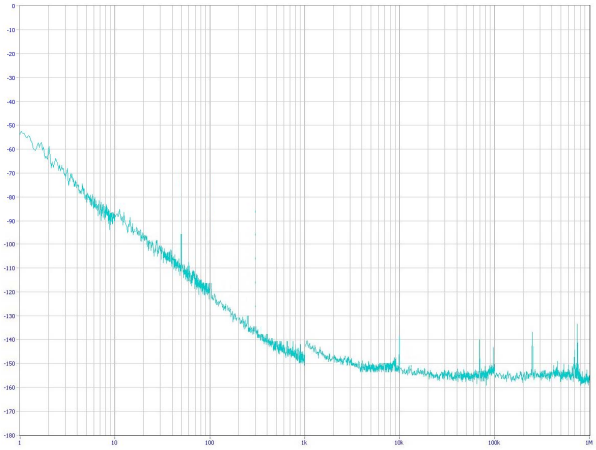

Figure 3. The phase noise of a 20MHz STCXO

From the experiments, we can see that because of without compensation circuit, the power consumption of the stress compensation oscillators is obviously lower than conventional TCXOs, and it has the advantages of small size, high frequency stability, lower phase noise and aging compared with conventional TCXOs. So, it should be developed in future.

III. CONCLUSION

We use the influence of stress on the frequency of crystal blank to compensate the temperature influence on the frequency of crystal. Here we not only omit the compensation circuit, but also utilize the advantage of overtone crystal. So the performances are all better than conventional TCXOs. Because of low cost, low power consumption and small size, this type of oscillators will be competitive in future.

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