Study on Quality Factor of the Ring Electrode QCM Resonator

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***Abstract*—The quality factor (Q-factor) is a key parameter for quartz crystal microbalance (QCM) resonator because it presents the stability of the resonance frequency of QCM resonator. However, it is few papers to report that the Q-factor of ring electrode QCM resonator. In this paper, we studied the Q-factor of ring electrode QCM resonator. The experimental results show that the ring electrode QCM resonators have a high quality factor(Q>6400). Therefore, the ring electrode QCM resonator has good frequency stability.**

***Keywords*—QCM; Q-factor; ring electrode;**

I. INTRODUCTION

As a popular type of piezoelectric sensor, the quartz crystal microbalance (QCM) has been widely used in many disciplines since the Sauerbrey theory was proposed [1]. QCM has a typical sandwich structure, that is, quartz plate in the middle and metal electrodes on the upper and lower surfaces. In 1959, Sauerbrey studied the relationship between the mass loading added on the electrode surface and the change in the resonance frequency, and pointed out that the increase in mass loading on the electrode surface leads to the decrease in the resonance frequency [1]. This relationship can be expressed as [1]:

$$\Delta f = -\frac{2f_0^2}{\sqrt{\mu_q \rho_q}}\frac{\Delta m}{A} \quad (1)$$

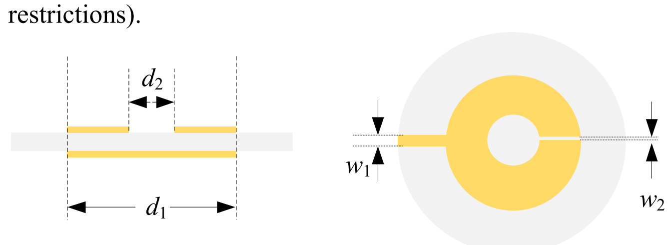
where Δm is the change of the mass loading; Δf is the change in resonance frequency; f_0 is the resonance frequency; A is the active electrode area; μ_q is the shear modulus of AT-cut quartz crystal; ρ_q is the density of quartz.

The mass sensitivity is one of crucial parameters of QCM sensor, it has attracted the attention of many researchers. F. Josse et al. pointed out the relationship between the radial mass sensitivity and the modified-electrode QCM resonators [2]. A. Richardson et al. achieved the uniform mass sensitivity distribution by a patterned electrodes for QCM [3]. Recently, X. H. Huang et al. proposed the ring electrode QCM to achieve the approximately uniform mass sensitivity distribution [4]. A QCM with double-ring electrode improving the uniformity of QCM mass sensitivity distribution was designed by H. F. Jiang [5]. However, the Q-factor of ring electrode QCM resonator was few reported. Therefore, it is necessary to clarify the Q-factor of the ring electrode QCM resonator.

In this work, we studied the Q-factor of ring electrode QCM resonator deeply. The experimental results showed that the ring electrode QCM resonators have a high quality factor(Q>6400). That is to say, the ring electrode QCM resonator has a good stability and it can be used reliably.

II. Q-FACTOR OF RING ELECTRODE QCM RESONATOR

The structure of the ring electrode QCM resonator is shown as Fig.1. The diameter of 10 MHz AT-cut quartz crystal and the disc electrode (d_1) are 8.7mm and 5.1mm, respectively. The thicknesses of the electrode and the quartz plate are 800 Å and 0.167 mm, respectively. The outer diameter and inner diameter of ring electrode is 5.1mm and 2mm. W_1 (W_1 = 0.5 mm) is the width of the electrode contact pads, and W_2 (W_2 = 0.3 mm) is the width of an opening in the ring electrode (manufacturing restrictions).



(a) **(b)**

Fig. 1. Structure of the ring electrode QCM. (a) Side view; (b) Top view.

It is well known that the Q-factor is one of the crucial parameters for QCM resonator and it indicates the stability of resonance frequency of resonator. Namely, the higher Q value of the resonator, the better the stability of its resonance frequency. Essentially, the Q factor presents the sharpness of resonance frequency, and it confirms the minimum change in the detectable frequency [6]. The Q factor can be expressed as [7]

$$Q = \frac{f_0}{2\Gamma} \quad (2)$$

where f_0 is the resonance frequency; 2Γ is half-bandwidth. From this equation, we can know that the Q factor is determined by the resonance frequency and half-bandwidth. Additionally, the Γ and f_0 are shown as Fig. 2.

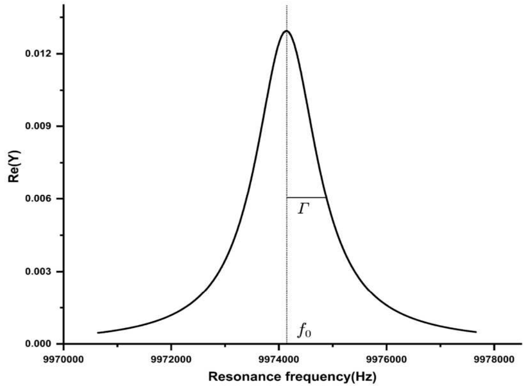


Fig. 2. Measurements of the resonance frequency and the half bandwidth.

III. Experimental Measurement Systems

In order to obtain the resonance frequency and half-bandwidth parameters of the ring electrode QCM resonators, we established the experimental measurement systems as shown Fig.3. The ring electrode QCM resonators were cleaned by ultrasonic cleaning equipment before starting measurement. In this measurement systems, the temperature in the cell is adjusted by the temperature controller Julabo 4; The resonance frequency of ring electrode QCM resonator is measured by the Agilent E5100A. Then the half-bandwidth of ring electrode QCM resonator is analyzed by the measurement data.

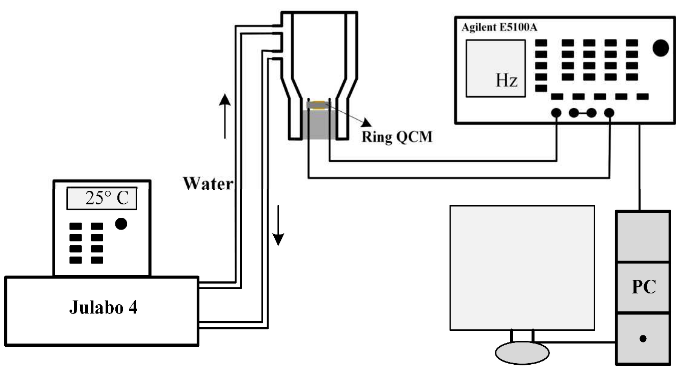


Fig.3 Experimental measurement system.

IV. Results

The Q values of QCM-1, QCM-2 and QCM-3 were calculated by the equation (2). The results are shown as Table I. The Q values of QCM-1, QCM-2 and QCM-3 are 7189, 6744 and 6437, respectively. On the other hand, the average and the variance of Q values are 6790 and 308.7. These ring electrode QCM resonators have the high Q values, and the results show that the ring electrode QCM resonators have good frequency stability. It should be noted that the average resonance frequency and variance of these three samples are 9975936.5 Hz and 66.7, respectively. The low variance shows that the measurement system is reliable.

Table I. The Q factor of QCM resonators

	f_0(Hz)	2Γ(Hz)	Q
QCM-1	9,974,142.6	1,387.4	7,189
QCM-2	9,973,676.1	1,478.9	6,744
QCM-3	9,979,990.8	1,550.4	6,437
Average	9,975,936.5	1,472.2	6,790
Variance	66.7	2,873.1	308.7

V. Conclusions

In this paper, we measured the Q values of the three AT-cut ring electrode QCM resonators with standard frequency of 10MHz. It is well known that the Q-factor is one of key parameters for QCM resonator, and it determines the stability of resonance frequency. However, the few papers reported this topic, especially for ring electrode QCM resonator. The experimental results showed that the ring electrode QCM resonators have a high quality factor (Q>6400). On the other hand, the ring electrode QCMs have the advantage in mass sensitivity distribution. That is to say, the ring electrode QCM resonator has a good stability and it can be used reliably.

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