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Viscoelastic analysis of 100-MHz SC-cut QCM method using drop method

Yingbo. Sun †, Yudai Maruyama, Yuta Aoki, Kengo Hara and Yasuaki Watanabe
(Grad. Sch. System Design, Tokyo Metro. Univ.)

1. Introduction

QCM (quartz crystal microbalance) has an advantage in that various objects can be easily evaluated[1,2]. An AT-cut crystal resonator is mainly used for QCM. The authors previously used an SC-cut crystal resonator to measure viscosity and density [2-4]. A 100-MHz SC-cut resonator was selected as the QCM element in order to clarify its characteristics[4]. However, when a network analyzer (hereinafter referred to as NA) was used to measure its characteristics in liquid, a noise overlap was found due to a low-resonance Q value [4]. Therefore, in this report, the drop method [5] was used. We compared 1) the minimum value of the resonance point of NA, 2) the minimum value obtained from the approximate value near the resonance point, and 3) the drop method [5]. Compared with this minimum part and value, the drop method was found to be the most appropriate. Then, the characteristics of the 100-MHz SC-cut QCM method and a calculation method for the drop method are described as suitable for very low viscosity liquids.

2. Measurement systems

Fig. 1 is a device for measuring QCM that has already been reported[3]. NA was calibrated in advance, and a cesium atomic clock (10^{-13}) was used as the reference frequency. The measurement temperature was maintained at 25.0 ± 0.1°C in liquid, and the NA drive level was set to 0 dBm | 50 Ω. As mentioned above, a 100-MHz SC-cut crystal resonator (with mirror surface) was used as the resonator.

Email : sunyingbo109@yahoo.co.jp

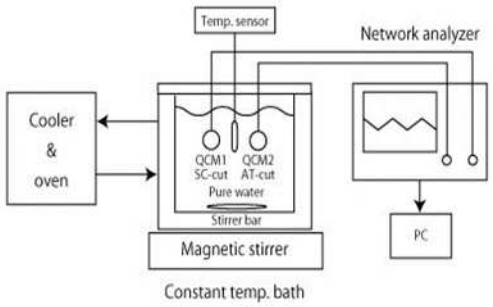


Fig.1 Experimental system

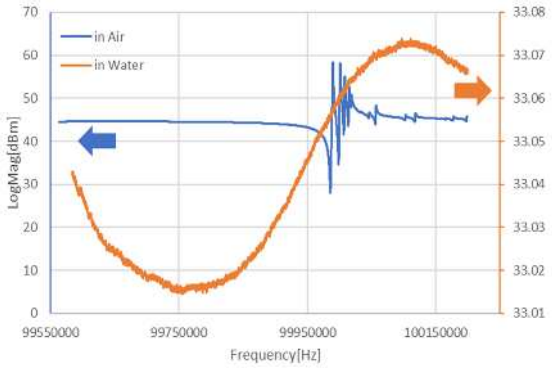


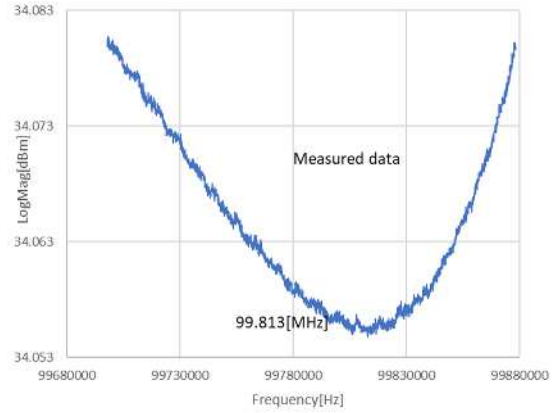
Fig.2 SC-cut in air and pure water

3. SC-cut in liquid

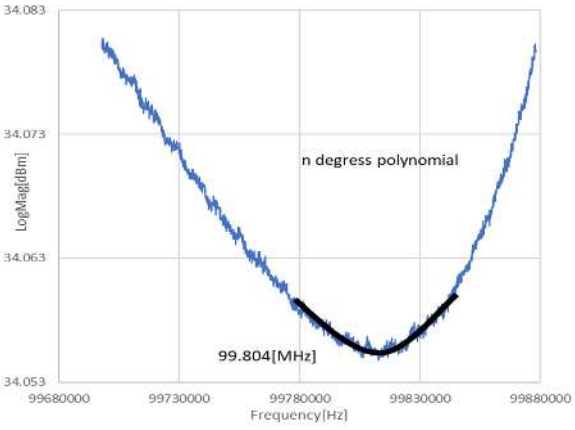
As shown in Fig. 2, when the 100-MHz SC-cut crystal resonator was in liquid, the stray mode was mixed with the main vibration mode, the Q value decreased, noise accumulated, and the resonant frequency could not be accurately detected. Such data must be processed by using the drop method to more accurately detect resonance frequencies.

4. Measurement results

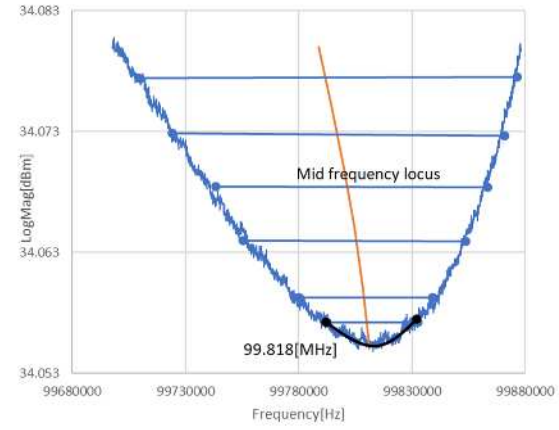
Figs. 3 (a) to 3 (c) show the minimum value (fs) of the NA resonance point, the approximate value of the resonance frequency (fs'), and the drop method (fs''). Regarding the drop method in Fig. 3 (c), two types of equal frequencies could be obtained



(a) fs



(b) fs'



(c) fs"

Fig.3 Measured results

Table 1 Measured results of deviation (n=10)

n=10	f_s	f_s'	f_s"
ppm	47.9	10.9	2.57
Frequency	99.815[MHz]	99.806[MHz]	99.818[MHz]

by first obtaining a quadratic approximation of the contacts on both sides of the resonance point and then connecting both contacts horizontally with a linear function. Furthermore, the linear function was quadratic approximated by the locus of the midpoint, and the region with the lowest amplitude was further quadratic approximated to obtain fs"(series resonance frequency).

As can be seen from Figs. 3 (a) to (c), the series resonance frequency deviated from fs to fs". To convert the amount of deviation, the same resonator was measured 10 times and is shown in Table 1. As can be seen from Table 1, the average value of 10 times is fs: 99.814825 [MHz], fs': 99.805574 [MHz], fs": 99.818463 [MHz]. The frequency deviations were 47.9 [ppm], 10.9 [ppm] and 2.57 [ppm], respectively, and it was found that fs″ of the drop method was the best.

5. Conclusions

When measuring the low Q value resonance frequency in a liquid using NA, it was found that the drop method fs″ was the best on average at 10 times. Thus, we would like to apply the drop method to a 100-MHz SC-cut QCM in a liquid.

Acknowledgments

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References

1. D. E. Pierce, et al., IEEE Trans. Ultrason. Ferroelectr. Freq. Control 45 (1998)
2. Y. Watanabe, J. Kondo, 77th JSPS Meeting (2016)
3. Y. Sun, et al., USE2021,13Pa2-6 (2021)
4. Y. Sun et al., The 66th JSAP Spr. Meet., (2022)
5. I. Koga, Electrical communication society (1983)