Development of a new CQCM/TQCM sensor to achieve good usability and temperature measurement

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Background – QCM: Contamination Sensor

Requirements for space use
- Wide temperature range : -190°C to +125°C
- Temperature measurement
- Frequency drift compensation

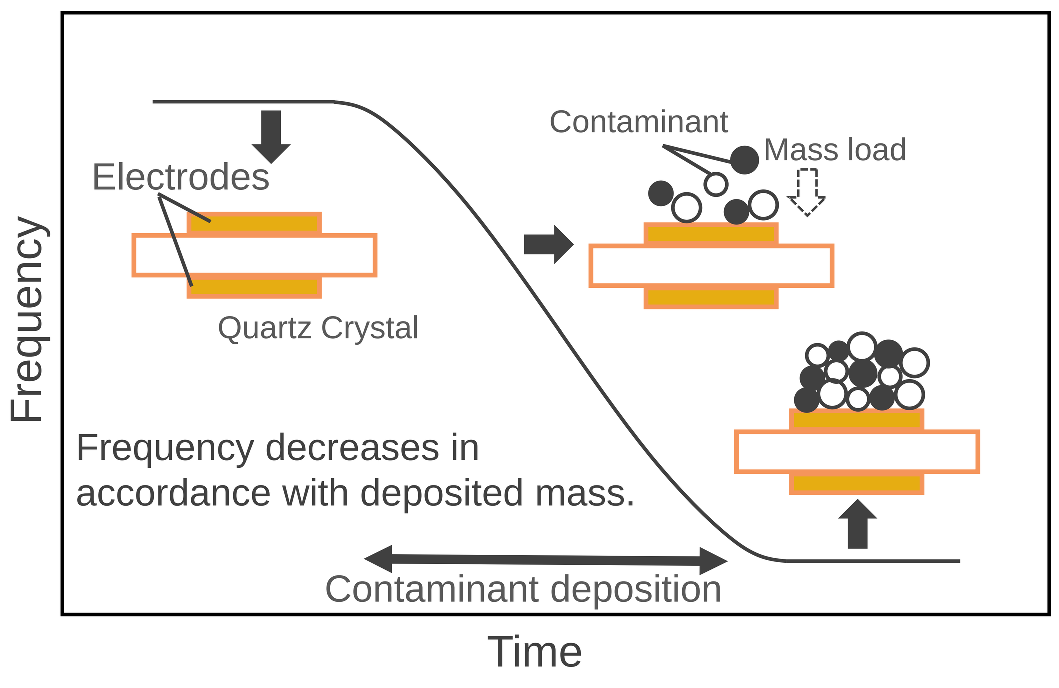


Fig. 1. Measurement principle of the QCM sensor

Our proposal for improving the QCM
- Sensor crystal replaceability for refreshment
- Temperature measurement with high accuracy
- Frequency drift compensation
- Usability

Fig. 2. Photos of the Twin-CQCM sensor unit (Left: unit with the cover; Right: unit without the cover)

Twin-electrode technique

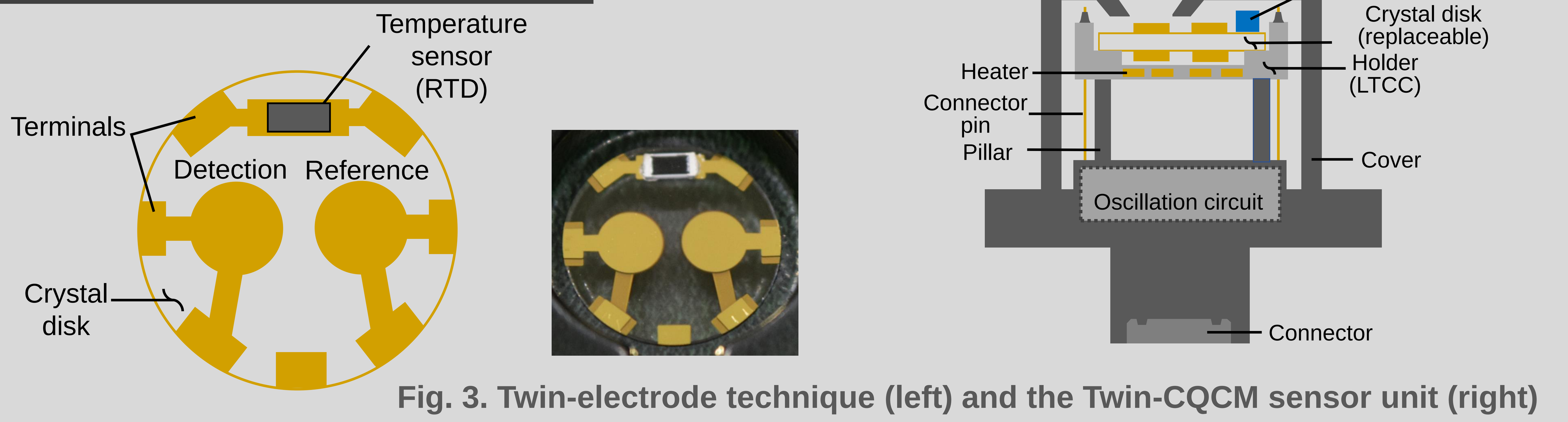
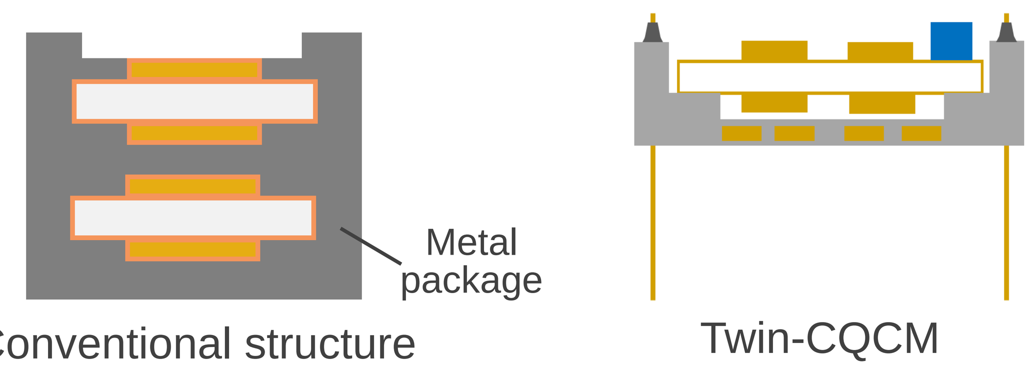


Fig. 3. Twin-electrode technique (left) and the Twin-CQCM sensor unit (right)

Advantages



- Simple structure.
- Frequency drift compensation. without crystal matching.
- Direct temperature measurement using free area on the crystal disk.
- Sensor replaceable by using small clips.
- Equivalence of each electrode's temperature condition.

Fig. 4. Concept comparison between conventional and Twin-CQCM

Some QCM sensors were developed for space use by using two sensor crystals. One sensor crystal is used to detect the deposited contaminant mass (F_d), and the other is used to detect the frequency drift caused by the temperature effect as a reference frequency value (F_r). Then the sensor output is $F = | F_d - F_r |$.

Table 1. Twin-CQCM specifications

Item	Value
Oscillation frequency	10.278 MHz
Crystal	AT-cut 14mmϕ
Mass sensitivity	(Fund.) 2.39 × 10^8 [Hz/(g/cm²)] (3rd.) 7.17 × 10^8 [Hz/(g/cm²)]
Heater power	Less than 9 W (typ. 3.5 W)
Temperature sensor	RTD platinum 1000

The Twin-CQCM sensor provides two kinds of signals: one for fundamental mode frequency (approx. 10 MHz), and the other for 3rd overtone mode frequency (approx. 30 MHz). In 3rd overtone mode, the sensor sensitivity is three times higher than that in fundamental mode.

Test Results

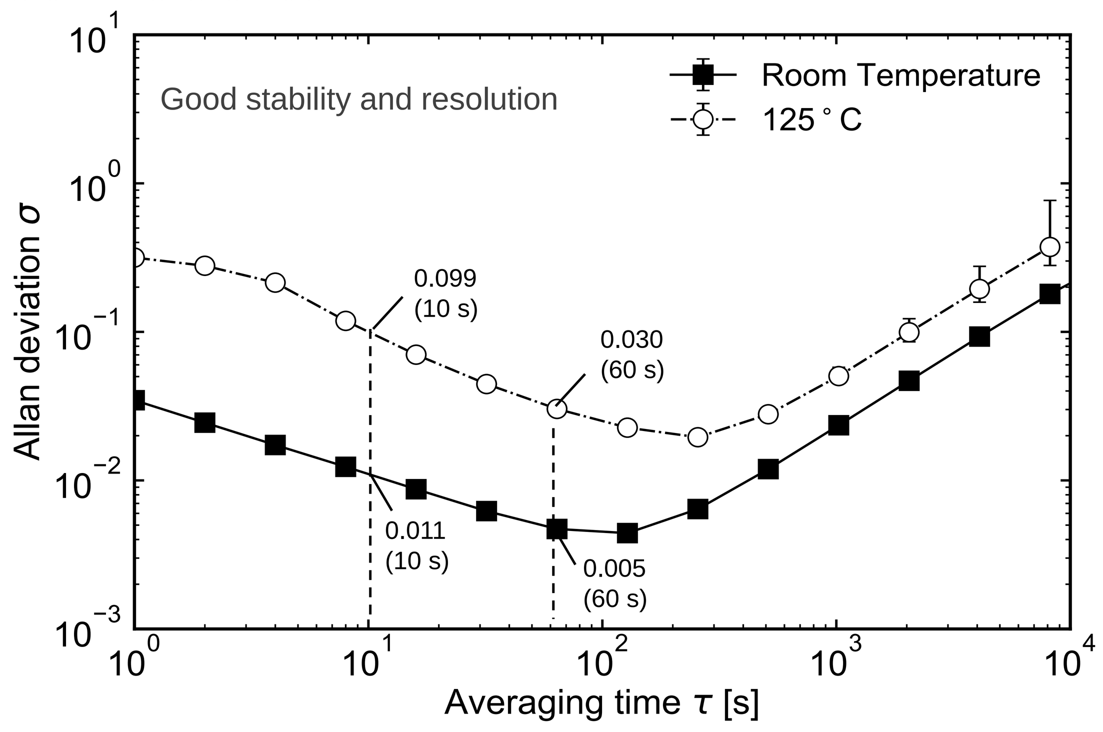


Fig. 5. Allan deviation of Twin-CQCM at room temp. and +125°C

When the averaging time is 10 seconds, the frequency deviation values were 0.011 Hz and 0.099 Hz at room temperature and +125°C.

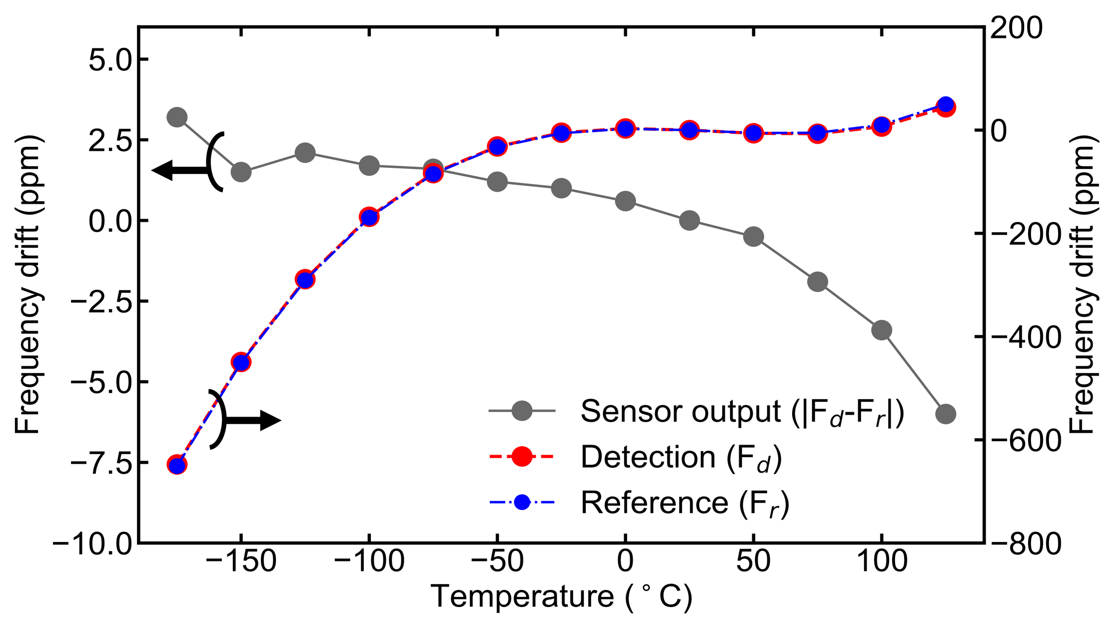


Fig. 6. Twin-CQCM frequency drift in fundamental mode

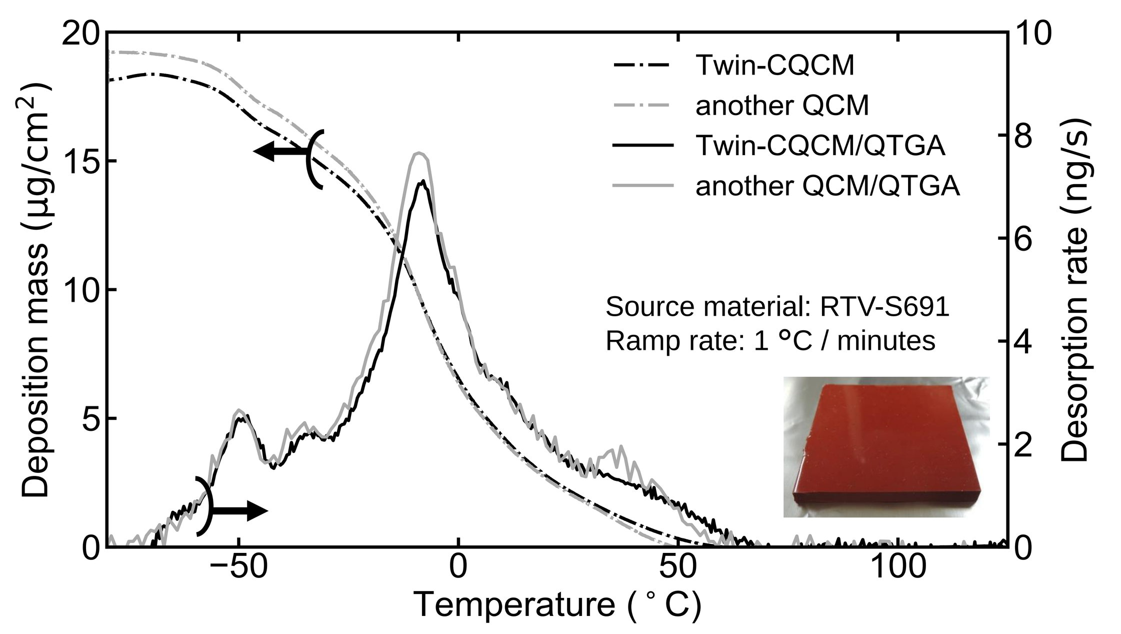


Fig. 7. Comparison between the QCM sensors by QTGA analysis

When looking at the QTGA spectrum in Fig. 7, the temperature and rate of the desorption peaks are almost the same. From these results, compatibility with another QCM sensor was confirmed.

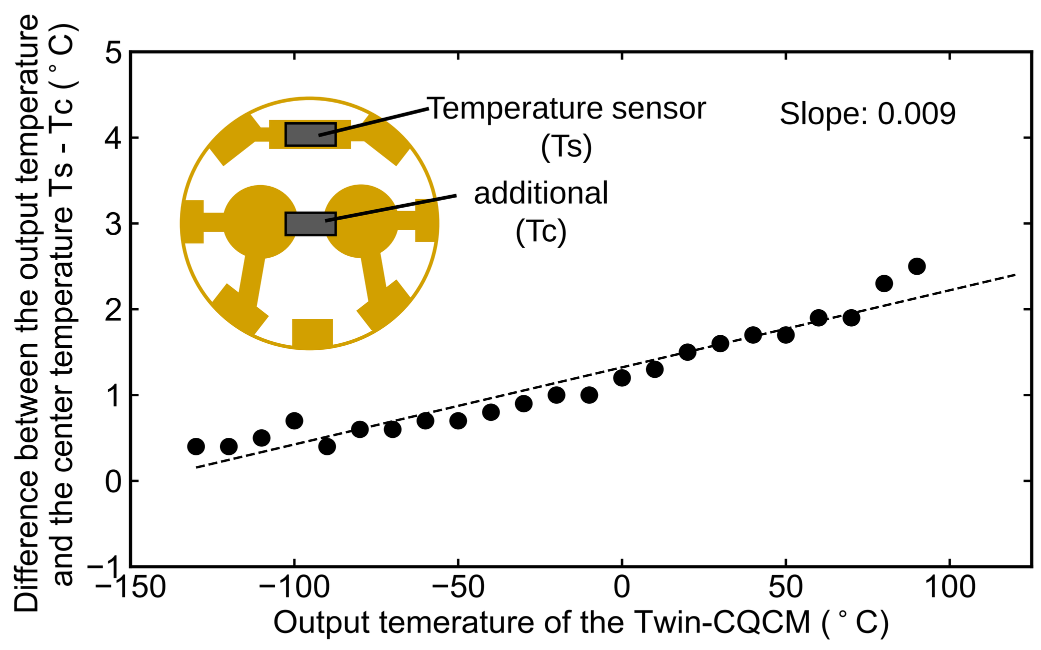


Fig. 8. Temperature measurement accuracy

To measure the center temperature of interest, an additional sensor (*Tc*) was installed. The difference between the two temperature sensors (*Ts* - *Tc*) was +0.4 to +2.6°C in the range of –130 to +100°C under cooling by liquid nitrogen.

New application – Atomic Oxygen measurement

- Easy sensor replacement

1. Open the sensor cover.
2. Remove the clips and the sensor crystal disk.
3. Put a new sensor on the LTCC holder.
4. Close the cover.

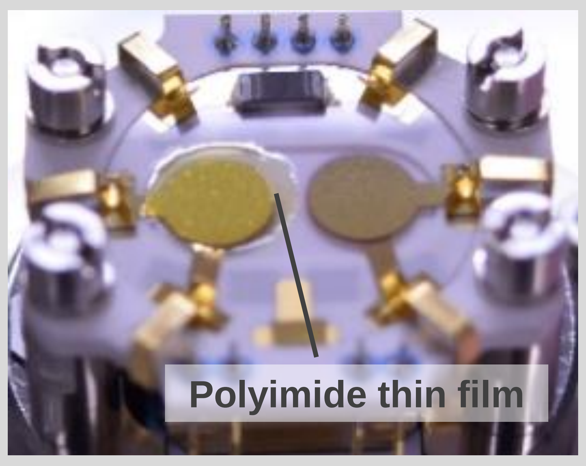


Fig. 9. The sensor crystal with a polyimide film coated using a spin coater on the sensor electrode

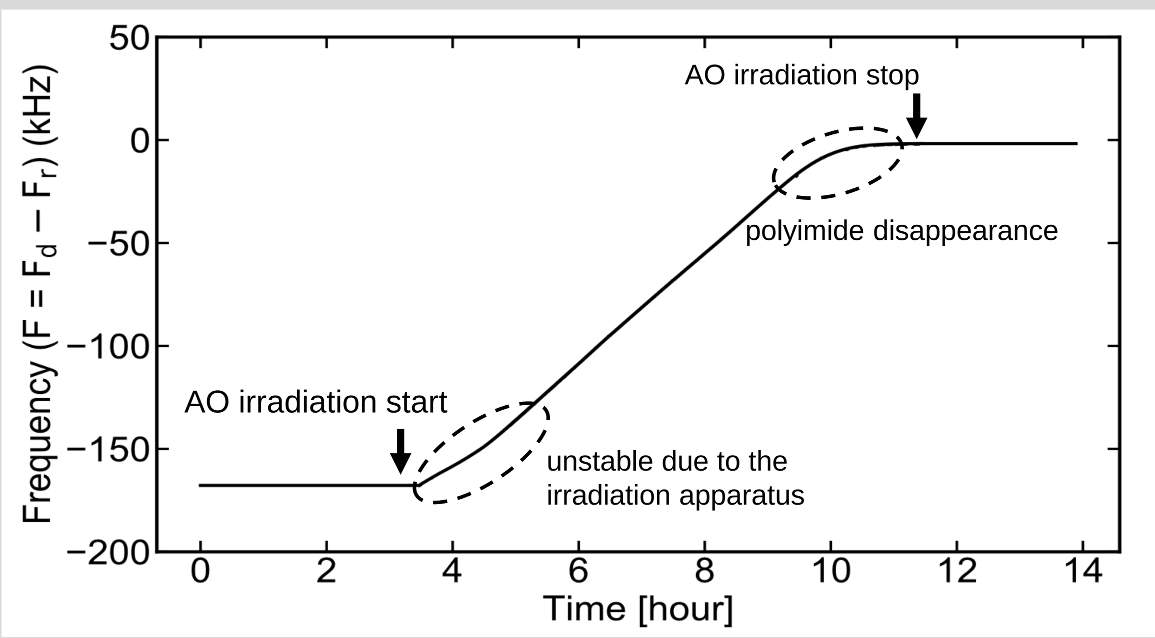


Fig. 10. AO flux measurement by the Twin-CQCM sensor with a polyimide thin film

Other advantages – Unique technical points

- **Long distance connection between the sensor unit and the controller**

The Twin-CQCM sensor guarantees a communication distance of at least 20 m using LVDS signals.

- **Twin-TQCM development**

The simplified structure is applicable to Twin-Thermoelectric QCM (TQCM) in terms of tolerance against shock and vibration environment because the weight of the LTCC holder is light. The consumer model (Twin-TQCM) has passed shock testing with a peak level of 1000 G.

Conclusion

- NDK and JAXA has developed the new QCM sensor.
- Twin-CQCM has sufficient performance to measure contamination deposition and TGA.
- Temperature measurement seems to be very reliable.
- This good usability enables not only simplified sensor replacement but also new applications, such as atomic oxygen (AO) measurement and the fixation of contaminants by ultraviolet (UV) irradiation.

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