Evaluation Results of New Contamination Sensor "Twin-CQCM" Developed by Japanese Manufacturer

07.19, 2017 CCMPP Workshop, NASA Goddard Space Flight Center

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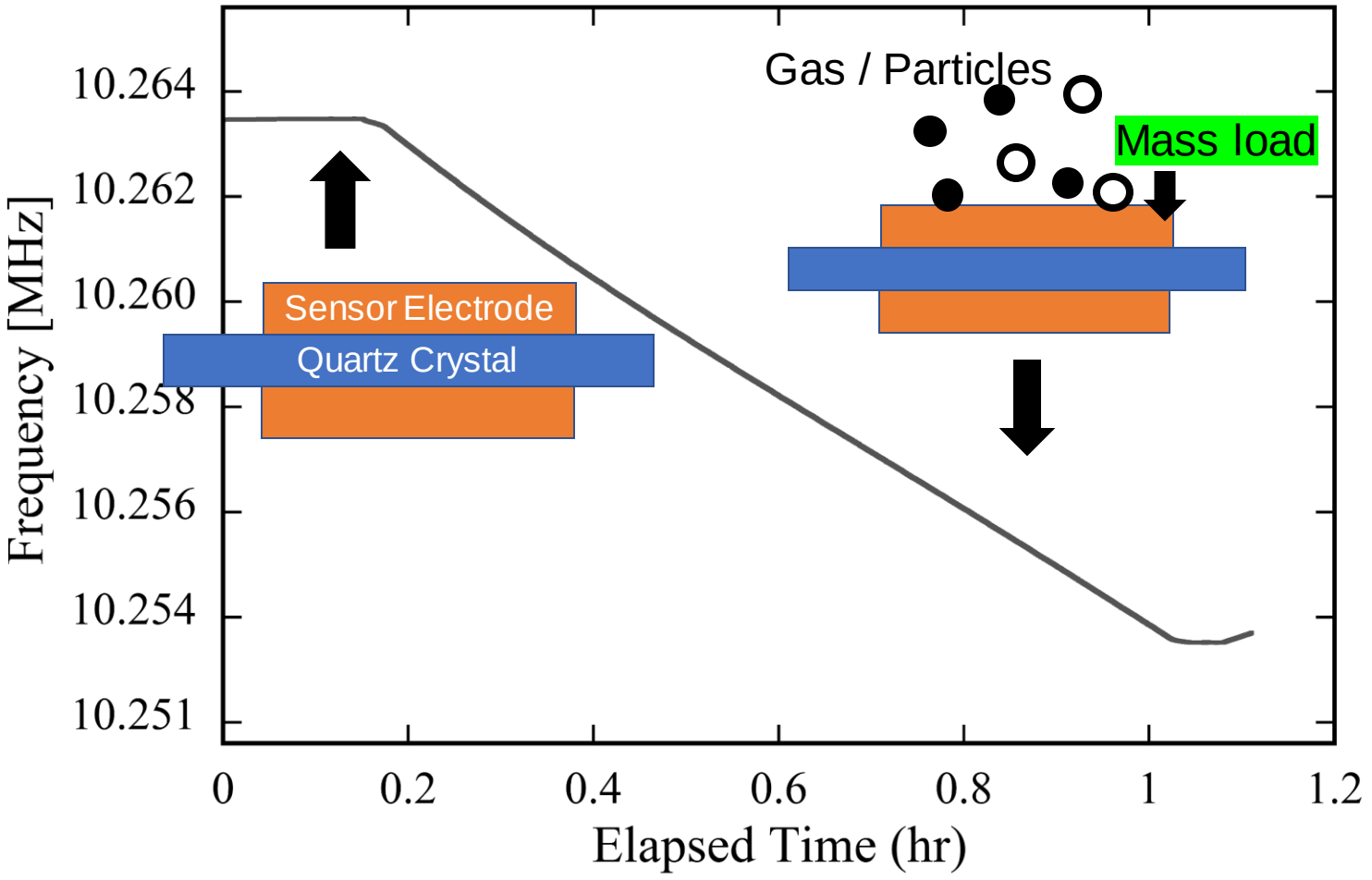
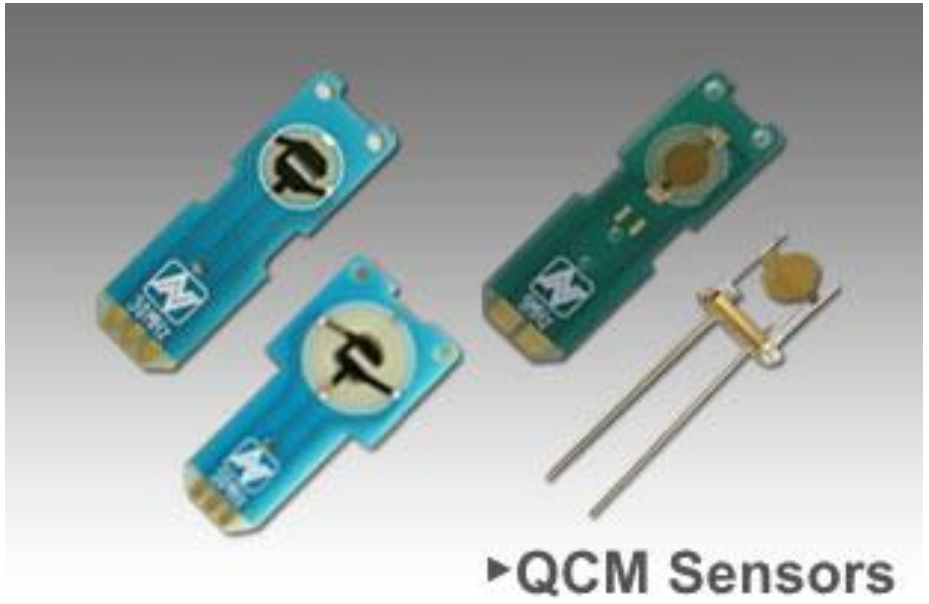
Introduction -Principle of QCM sensor-



- QCM sensors detect mass load of quartz crystal surface.
- Frequency decreases depending on mass.



Courtesy of NDK
http://www.ndk.com/en/products/search/biosensor/

Introduction

- NDK (Nihon Dempa Kogyo Co., LTD.) and JAXA have developed a new contamination sensor device, **“Twin-CQCM”**.
- The development has been completed in January, 2017.
- These products have already been patent-pending

Twin-CQCM sensor module

Twin-CQCM sensor controller (4 channels)

Product Concept

- Wide temperature range: -193 ~ +125 °C
- High accuracy temperature measurement at sensor crystal itself
- Good temperature effect compensation
- Good sensitivity using 3rd overtone of quartz crystal
- Enough thermal conductivity for cooling
- Easy sensor replacement by user
- Visualization of raw frequency data
- Long Cable availability by high quality data transmission for vacuum chamber

Overview -Sensor specifications-

Twin-CQCM sensor module

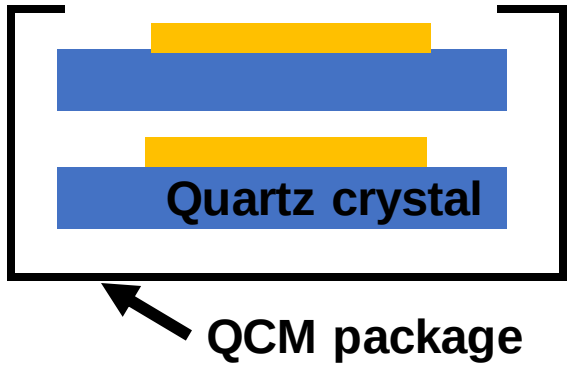
Twin-CQCM sensor controller

Item	Content
Fundamental Frequency	10.284 MHz
Crystal blank basic specs.	AT-Cut Polish ϕ14 mm Twin-electrode type
Mass Sensitivity	2.39×10^8 (Fund.) [Hz/g/cm^2] 7.17×10^8 (3rd Over Tone) [Hz/g/cm^2]
Mass Range	4.18×10^{-4} (Fund.) [g/cm^2] 2.39×10^{-5} (3rd Overtone) [g/cm^2]
I/O Interface	Nano miniature D-sub 15 pins
Frequency Signal Output Level	LVDS
Heater Power	< 9 [W]
Temperature Sensor	Platinum RTD 1000

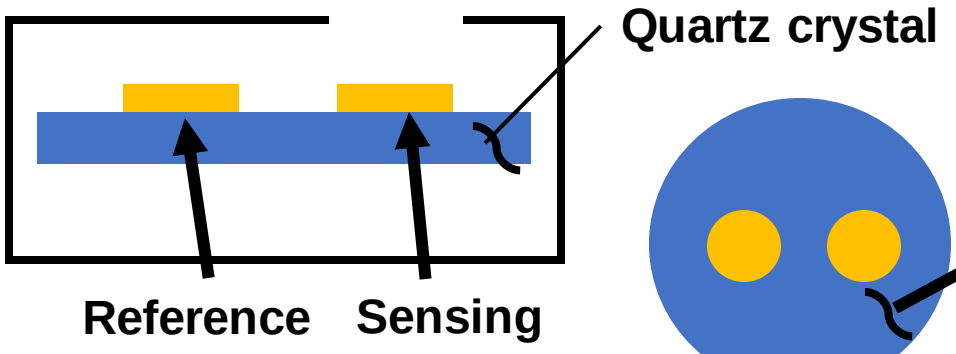
Twin-electrode quartz crystal technique

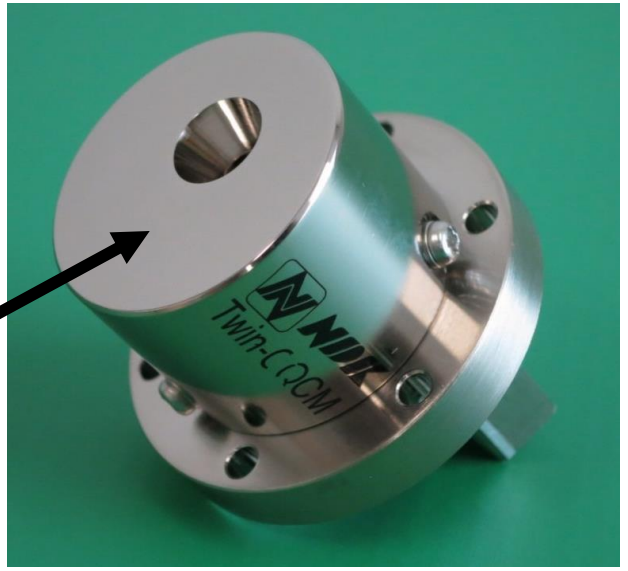
- One crystal quartz disk has two electrodes. One is for sensing and the other is for reference to compensate frequency shift caused by temperature effect.
- Based on the technique, the frequency shift can be compensated without crystal matching method.
- Temperature condition of the two electrodes sensing area is almost equivalent.

Conventional Technique



Twin – QCM (new!)





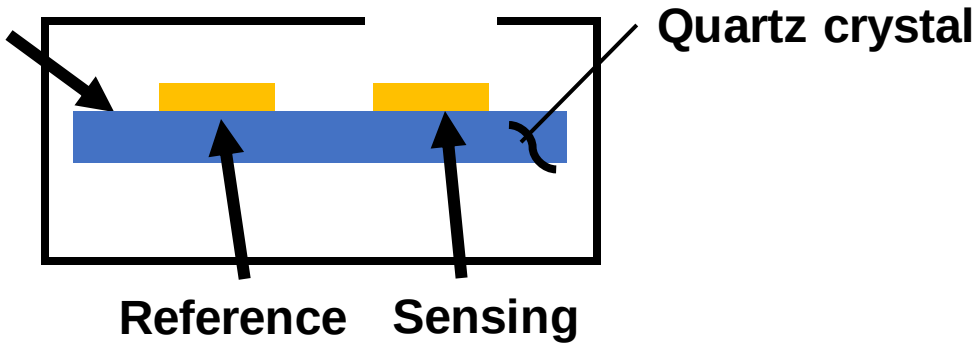
- ✓ Simple structure
- ✓ Miniature size
- ✓ Without crystal matching
- ✓ Sensor lid covers the reference electrode

Twin-electrode quartz crystal technique

- Precise temperature measurement is very important because it can govern the experiment result easily.
- Therefore, it is better to measure the temperature directly at the crystal surface.

- Platinum RTD sensor measures temperature at the surface of quartz crystal **directly** using the four-terminal method.

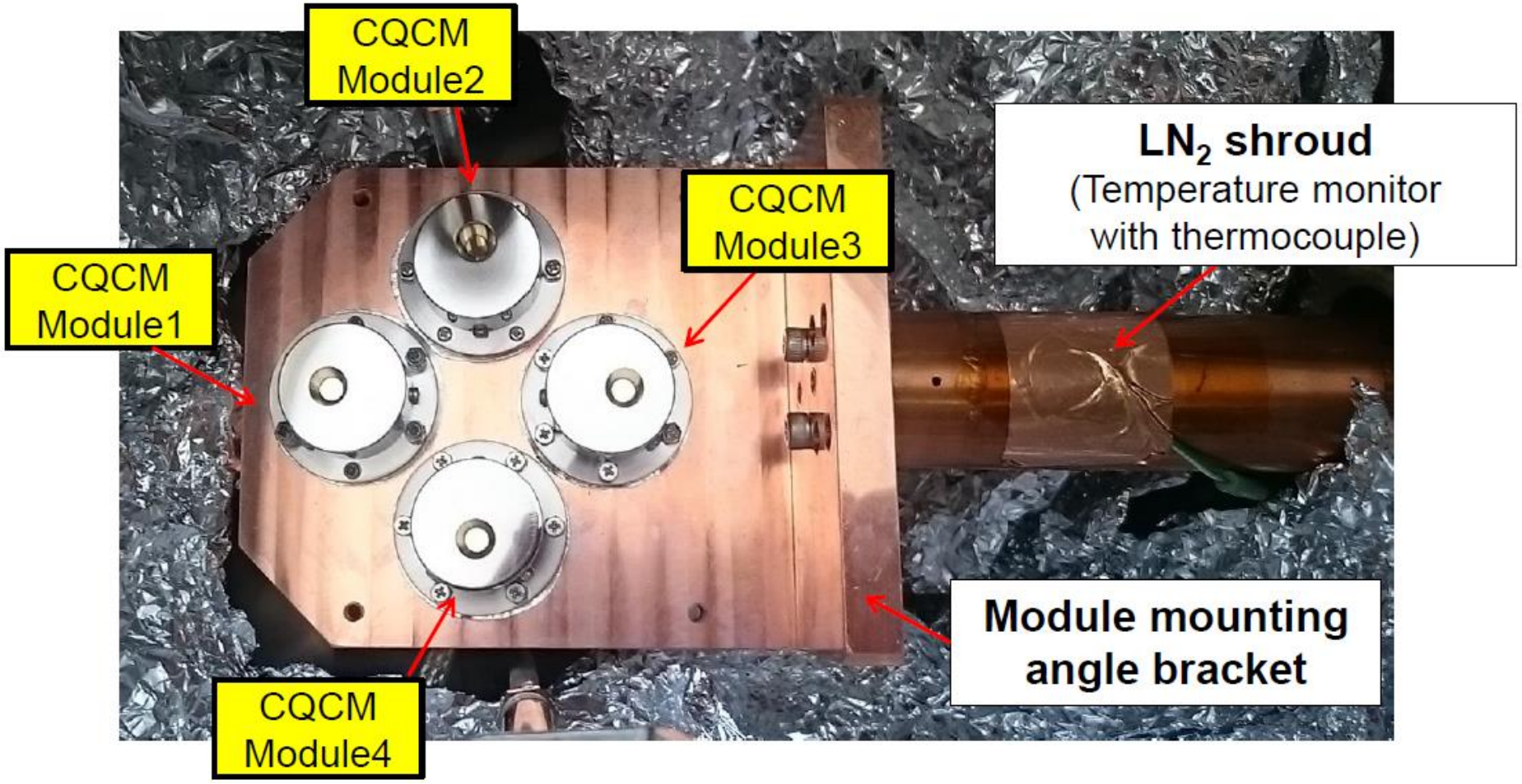
Temperature sensor detects quartz crystal temperature directly.



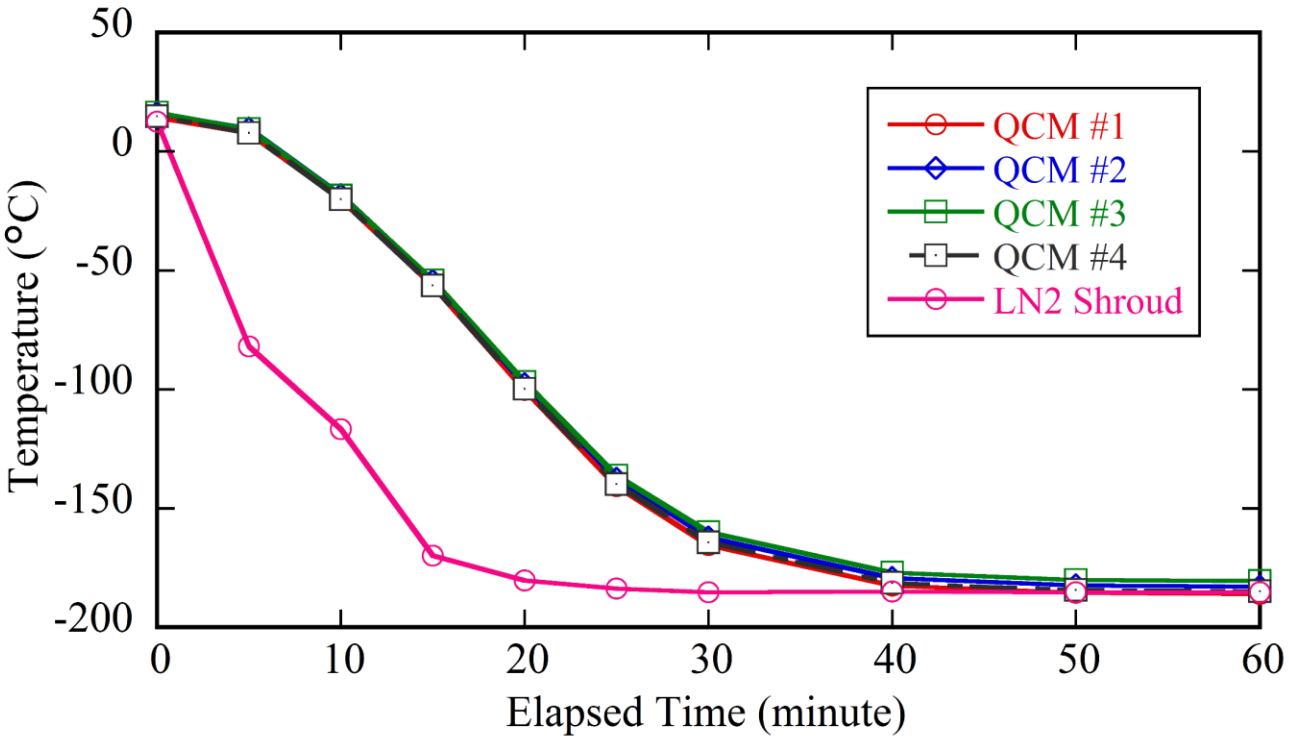
Evaluation Test Setting

Crystal Bridge to the Future

Module installation state in simple vacuum chamber for commercial sample evaluation

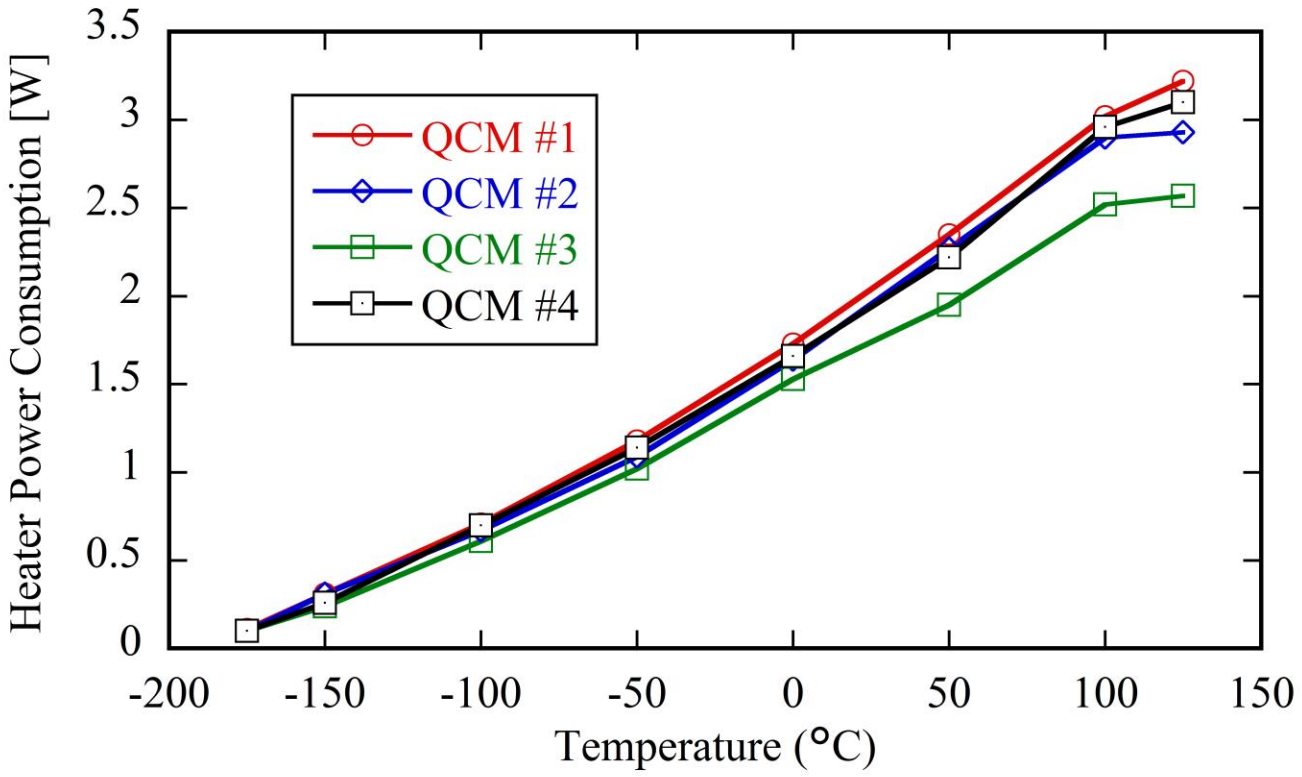


Cooling characteristics



Elapsed time (minute)	Temperature (°C)				
	QCM #1	QCM #2	QCM #3	QCM #4	LN2 shroud
0	14.3	16.2	16.4	14.8	12.5
5	7.8	9.6	9.4	7.8	-81.9
10	-20.1	-18.3	-18.5	-20.1	-116.8
15	-56.3	-54.4	-54.2	-56.3	-169.9
20	-100.2	-97.8	-96.8	-99.8	-180.3
25	-140.6	-137.6	-136.3	-139.8	-183.7
30	-165.4	-162.2	-159.9	-164.3	-185.3
40	-182.4	-179.3	-177	-181.3	-184.9
50	-185.5	-182.3	-180.1	-184.3	-185.3
60	-186	-182.8	-180.6	-184.8	-185.3

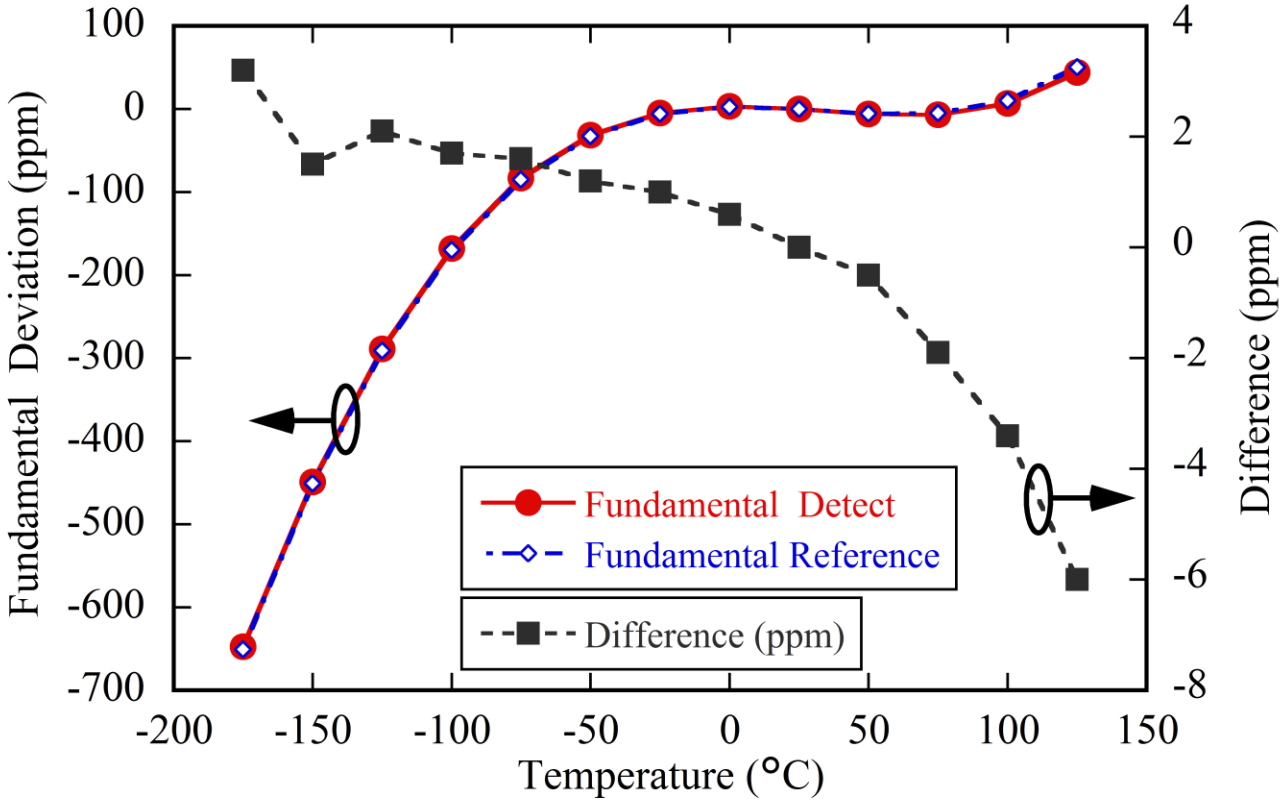
Heater power characteristics



Temperature (°C)	Heater Power [W]			
	QCM #1	QCM #2	QCM #3	QCM #4
-175	0.11	0.1	0.1	0.1
-150	0.31	0.31	0.24	0.26
-100	0.71	0.67	0.61	0.7
-50	1.18	1.09	1.02	1.14
0	1.73	1.64	1.53	1.66
50	2.35	2.27	1.95	2.22
100	3.02	2.9	2.52	2.96
125	3.22	2.93	2.57	3.1

- Through the heating, the heat sink was kept at around -190 °C (LN2)

Fundamental oscillation characteristics



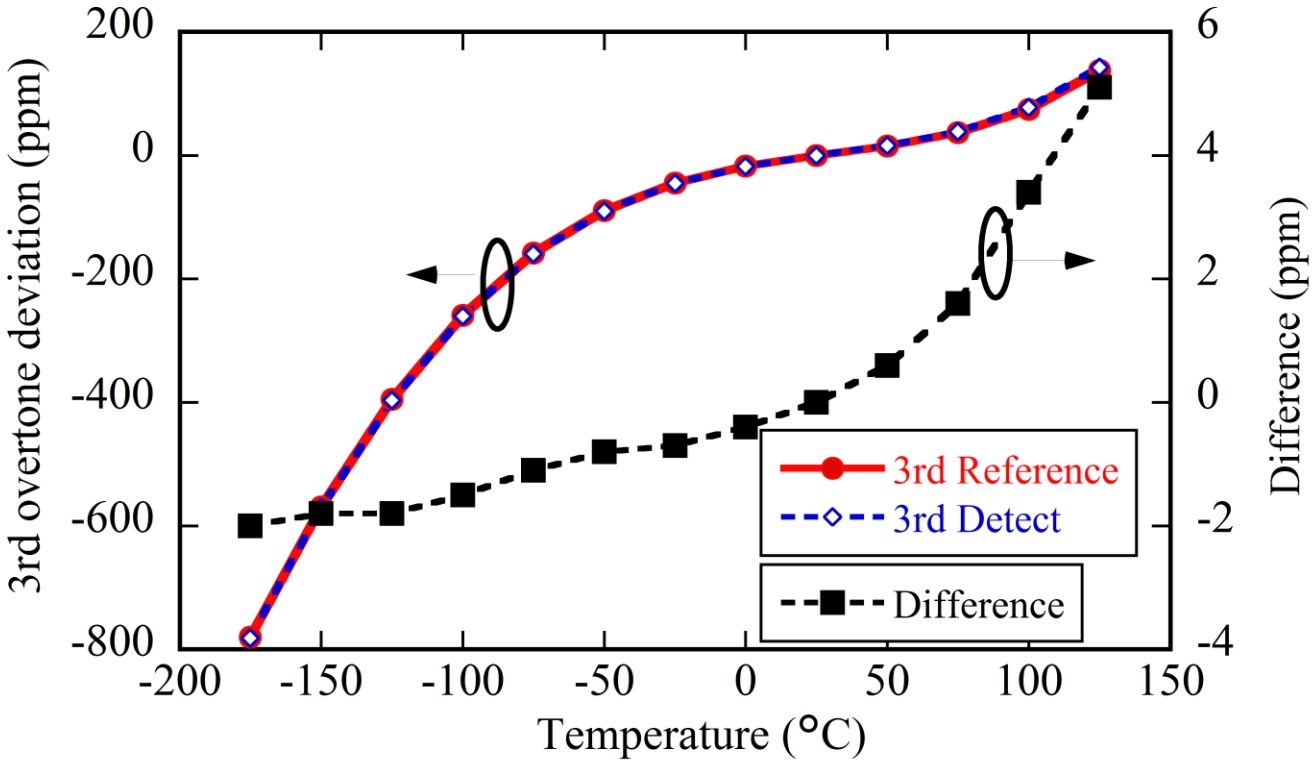
- Good temperature compensation characteristics
- Temperature range of -175 ~ +125 °C
- Fundamental frequency deviation is less than ±10 ppm.

Test conditions

Degree of vacuum	< 10^{-4} Pa
Temperature ramp rate	5 °C / min

Temp. (°C)	-175	-150	-125	-100	-75	-50	-25	0	25	50	75	100	125
Fund. DET (ppm)	-647.7	-449.2	-288.8	-167.9	-83.4	-31.7	-5	3.2	0	-6.1	-7	6.8	44.2
Fund. REF (ppm)	-650.9	-450.8	-290.9	-169.6	-84.9	-32.8	-6	2.6	0	-5.6	-5.1	10.2	50.3
Difference (ppm)	3.2	1.5	2.1	1.7	1.6	1.2	1	0.6	0	-0.5	-1.9	-3.4	-6

3rd Overtone oscillation characteristics



- Good temperature compensation characteristics
- Temperature range of -175 ~ +125 °C
- Fundamental frequency deviation is less than ±10 ppm.

Test conditions

Degree of vacuum	< 10^{-4} Pa
Temperature ramp rate	5 °C / min

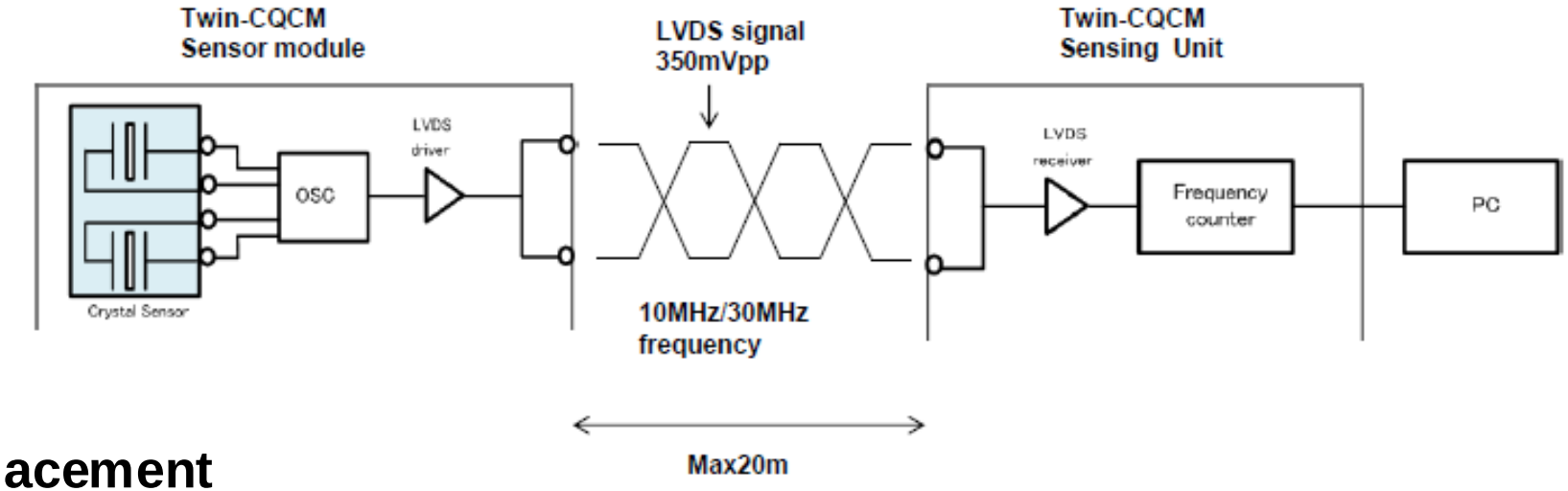
Temp. (°C)	-175	-150	-125	-100	-75	-50	-25	0	25	50	75	100	125
3rd OT DET (ppm)	-781.8	-570.8	-396.5	-260.3	-159.6	-90.2	-45.3	-17.7	0	15.8	38.6	77.7	142.4
3rd OT REF (ppm)	-779.8	-569	-394.7	-258.8	-158.5	-89.4	-44.6	-17.3	0	15.2	37	74.4	137.3
Difference (ppm)	-2	-1.8	-1.8	-1.5	-1.1	-0.8	-0.7	-0.4	0	0.6	1.6	3.4	5.1

Usability

- **Long distance connection**

LVDS keeps the signal level using the buffer to assure long distance data stream.
It is confirmed that over 20 m cable is available at least.

*LVDS: ANSI/TIA/EIA-644 standard



- **Sensor replacement**

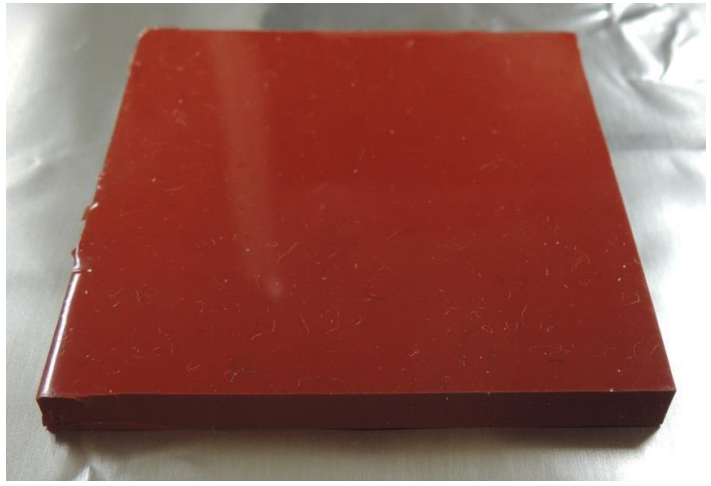
For instance, when kind of contaminant is stacked on the sensor surface, users can replace the sensor crystal within 5 minutes.

1. Open the lid, 2. Replace the sensor, 3. Close the lid.

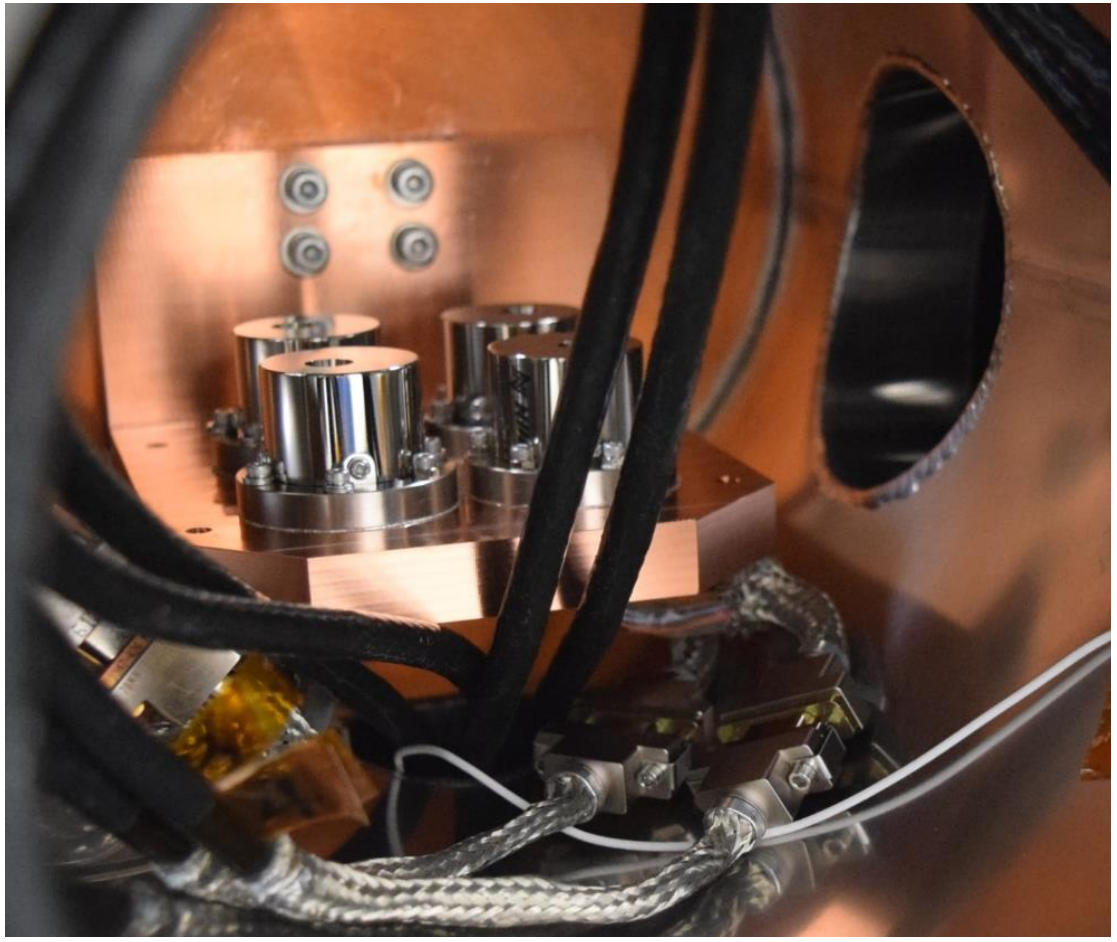
Contamination Test

Contamination test setup

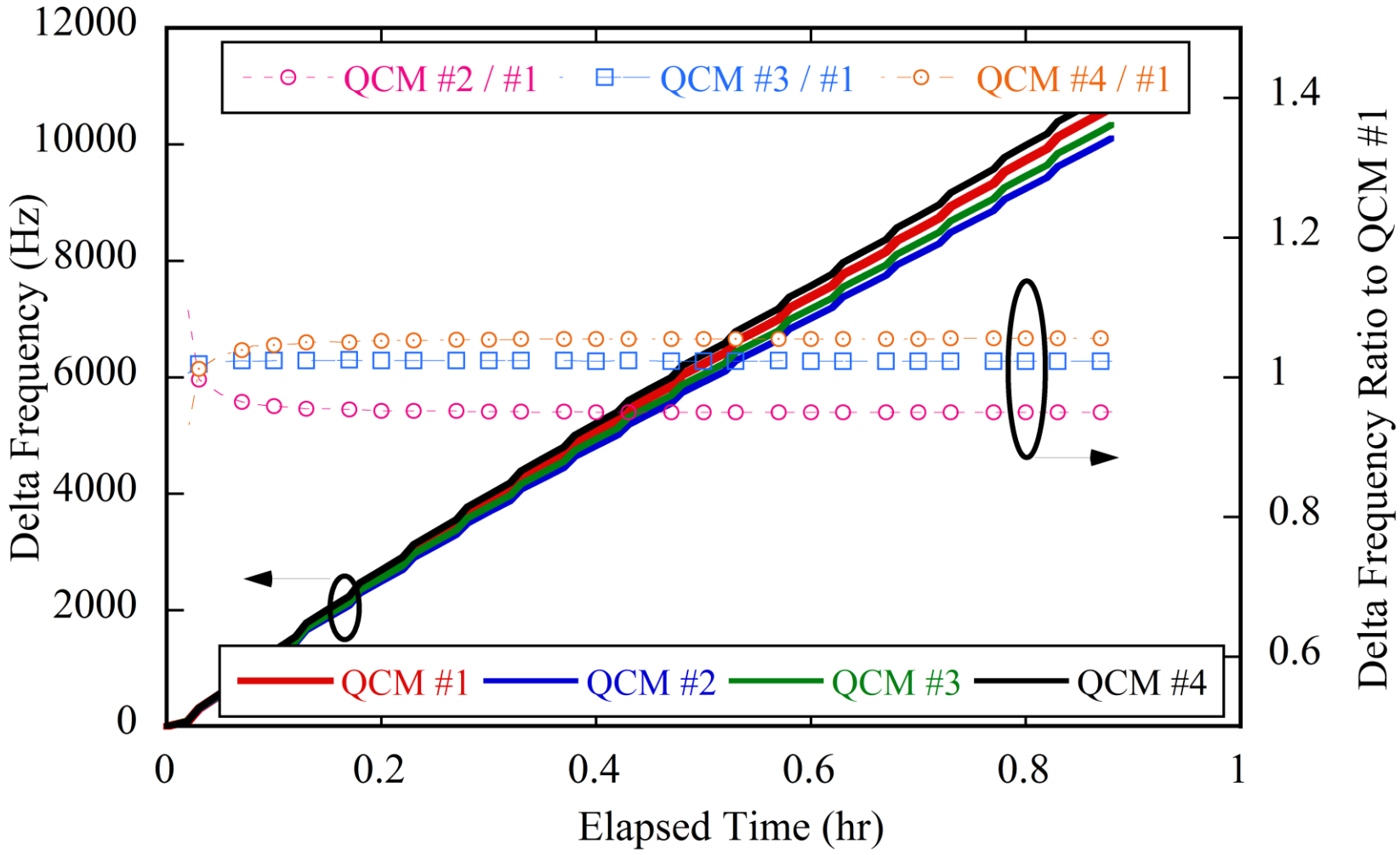
Item	Contents
Contaminant source	RTV-S691
Temperature at Contaminant source	+125 °C
Temperature at Twin-CQCM sensor	-170 °C for 1 hour



RTV-S691

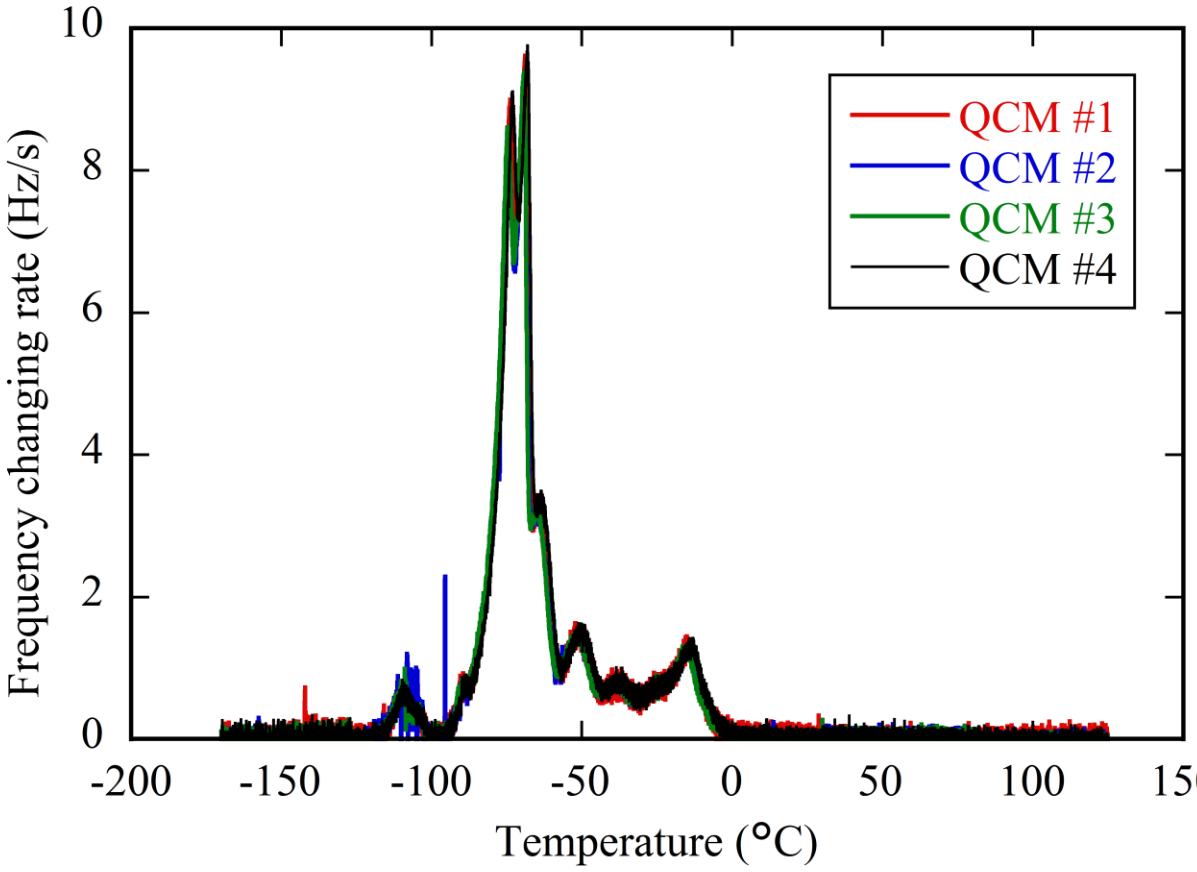


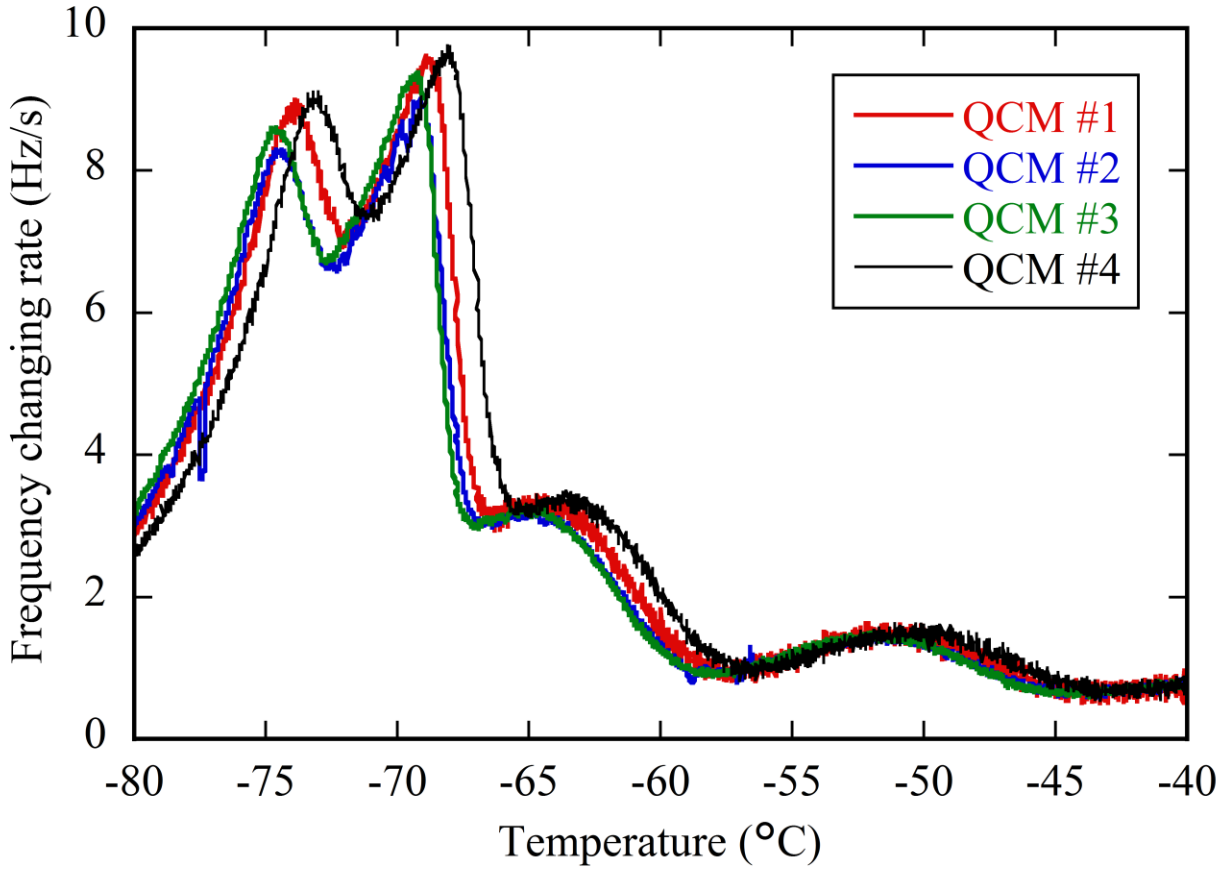
Contaminant deposition



- Very stable
- Difference between the sensors: < ±10 %
- The heat sink temperature: -170 °C

TGA Result





- Difference among sensors is within ±1.5 °C.

Conclusion –Twin-CQCM

Crystal Bridge to the Future

◆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:

Difference among 4 Twin-CQCM was within ±1.5 °C at any temperature based on the QTGA spectrum.


Thank you for your attention