

RX-9

- CO2 Gas Sensor
- Minimal Size
- Stable Operating
- Very Good Price

EXSEN INC, CERAMICS BASED ELECTRO-CHEMICAL TYPE SENSOR

Gas Sensor Manufacturer

EXSEN

COMPANY PROFILE



가스 센서 전문 기업 (주)엑센

- Since 2012.10, Ceramic based Gas Sensor Start-up
- Air Quality Monitoring Sensor & Module Manufacturer
- Located in Daejeon, South of Korea
- Korea, Global 300 company



Biz Area



Pollutions

- Gas**
(CO₂, CO, VOCs...) CO₂ Gas Sensor
- Dust**
(Toxic mold, Lead, Radon, Bugs, Dust mites, Smoke...)
- Bacteria**
(Bacteria, Pollens, Fungi, Vireses...)

CEO

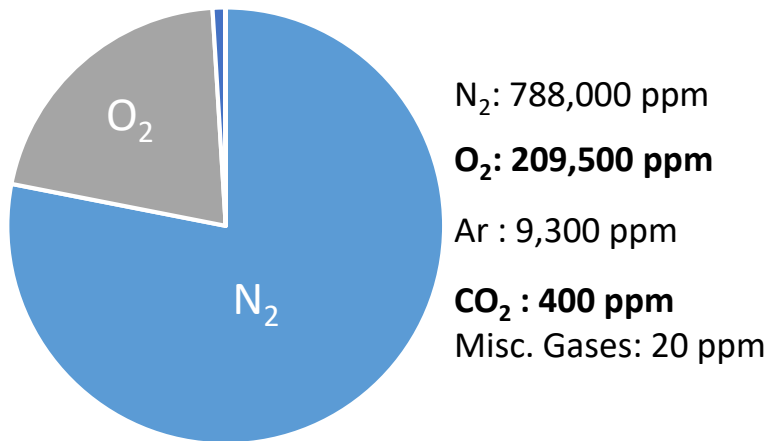
- Kim Jun woong, Ph.D, KAIST(Korean Institute of Science and Technology)
- Patent (Original Sensor Material Patent, Sensor Operating Algorithm)

Organization

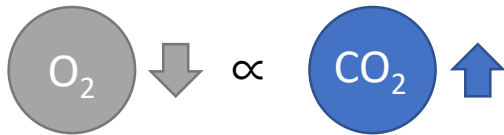


CO₂ GAS SENSOR

Atmospheric air (Earth)

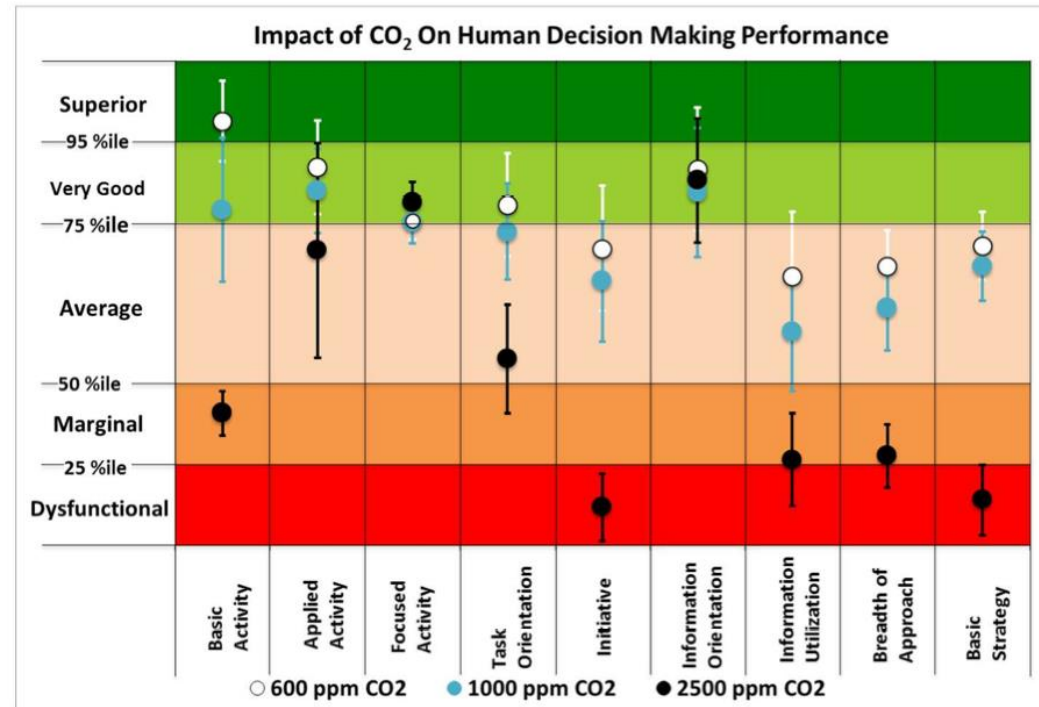


CO₂ Sensor



- O₂ decreasing means CO₂ increasing
- Change amount of Indoor O₂(CO₂) concentration: 0~5,000 ppm
- O₂ change rate <5% (5,000 ppm / 209,500 ppm)
- CO₂ change rate >1000% (5,000 ppm / 400 ppm)

CO₂ sensing is more accurate compare with O₂ measurement to determine the indoor O₂ concentration.



Ref. Elevated Indoor Carbon Dioxide Impairs Decision-Making Performance, Berkley Lab

O₂ consumption of brain



Brain is only
2% of Human
Weight
20% of O₂
consumption

이산화탄소(CO₂)

정의

- 탄소나 그 화합물이 완전히 연소되거나 생물의 호흡 또는 발효 할 때 생성되는 기체
- 무색, 무취
- 상온/상압에서 비활성 기체
- 1.977g/L로 공기 대비 60% 정도 높은 밀도
- 대기의 약 0.035%~0.045%(약 400 ppm)를 차지함

생성

- 공업적으로 석회석에 산을 가하거나 석회석을 가열해서 얻음
- 알코올과 같은 탄소화합물이 연소할 때 물과 함께 생성
- 생물체가 유기물을 분해하는 과정(발효)에서 생성
- 생명체는 호흡을 통해 유기물을 분해하면서 생명유지에 필요한 에너지를 얻는데, 이때 이산화탄소가 생성되어 날숨을 통해 공기 중으로 배출됨

이산화탄소 농도 기준

- 단체별 실내 환경 기준치(ppm)

오염물질	실내 환경 기준치(ppm, 이하 유지)		
	일본 건축기준법	WHO Europe	ASHRAE(미국)
이산화탄소	1,000	920	1,000

- 나라별 실내 환경 기준치(ppm)

오염물질	실내 환경 기준치(ppm, 이하 유지)				
	대한민국 (기계환기)	대한민국 (자연환기)	캐나다	싱가포르	일본 (문무과학성, 학교)
이산화탄소	1,000	1,500	3,500	1,000	1,500

인체에 미치는 영향

CO ₂ 농도	영향	장소 예시
<450	건강한 환기 레벨	
~700	장시간 노출되어도 문제 없는 실내 수준	
~1,000	건강에 피해는 없지만, 불쾌감 느끼는 사람이 있는 수준,	사무실
~2,000	졸림을 느끼는 등 컨디션 변화가 있는 수준	고속버스 엘리베이터 한겨울/한여름 가정집
~3,000	어깨 결림이나 두통을 느끼는 사람이 있는 등 건강 피해가 생기기 시작함	지하철
~4,000	눈, 목 점막 자극, 두통, 귀울림, 어지러움, 혈압상승	
~6,000	호흡수 증가	
~8,000	호흡 곤란	
~10,000	2~3분 이내에 의식 상실, 시력 장애	
~20,000	사망	

A study of CO₂ influence on student activity in classroom

Table 3

Average student results at each part and CO₂ concentrations during the seminary period

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10
Part 1	8.76	8.79	8.72	8.72	8.63	8.74	8.80	8.79	8.59	8.80
CO ₂ - part 1[ppm]	792	573	732	785	1717	889	439	968	2184	693
Part 2	9.31	9.35	9.17	9.39	9.11	9.26	9.24	9.13	8.95	9.32
CO ₂ - part 2[ppm]	1030	866	1949	572	1853	1601	1575	1830	2129	1064

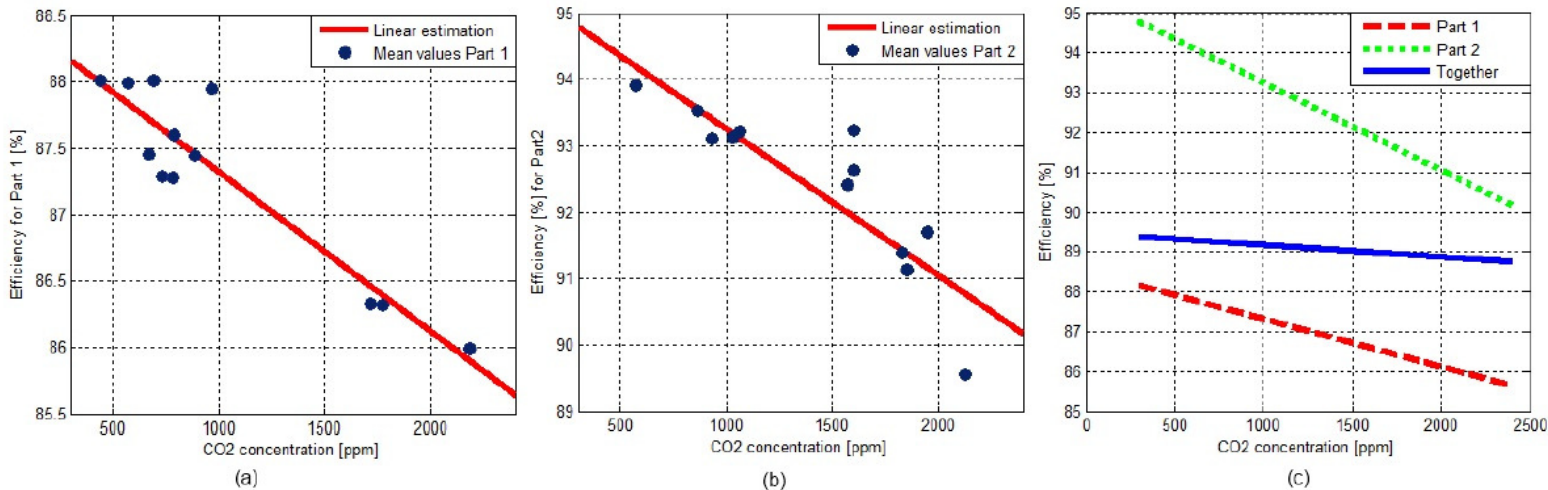


Fig 4 Estimation of efficiency for: a) part 1, b) part 2; c) together based on CO₂ concentration



Three Key Factors of IAQ

Freshness

Carbon Dioxide



Comfort

Temperature/Humidity




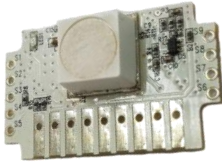

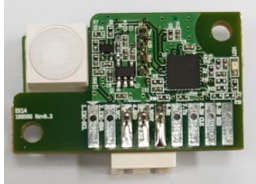
20°C 60%RH

Cleanliness

Airborne Particles

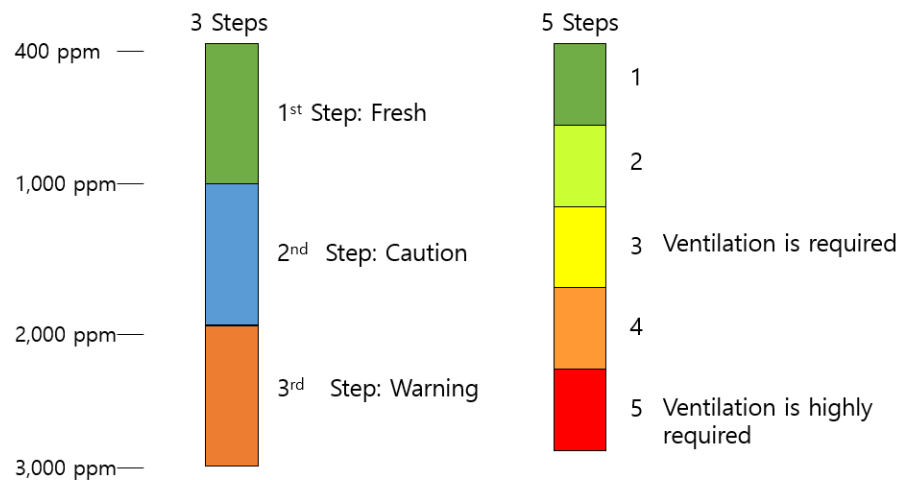


Product (CO2 Gas Sensor)

Model	HX-105N	LX-100	EX-7	BX-8	RX-9	EX-14
Picture						
Dim. (WxLxT,mm)	35 x 21 x 14.4		35 x 21 x 7.1	32.2 x 19.6 x 7	20 x 12 x 6.4	35 x 21 x 6.4
Feature	<ul style="list-style-type: none"> Wide operating temperature Very high humidity resistance Various Communication (I2C, UART, AVO) 	<ul style="list-style-type: none"> Outdoor Application Resin coated PCB to proof moisture 	<ul style="list-style-type: none"> Wide Operating Voltage Low thickness Good price Fast Feedback 	<ul style="list-style-type: none"> Compatible with other CO2 sensor 	<ul style="list-style-type: none"> Smallest CO2 sensor 2 Voltage output No MCU Very low price Calibration information with QR code 	<ul style="list-style-type: none"> Low thickness Low price Various Communication (I2C, UART, AVO)
Op. Volt (V)	3.5 ~ 5.5	5.5 ~ 13	3.2 ~ 5.5	3.2 ~ 5.5	3.2 ~ 3.4	3.5~5.5
Op. Temp (°C)	-40 ~ 85	-40 ~ 85	-40 ~ 60	-40 ~ 60	-20 ~ 60	-40~60
Application	<ul style="list-style-type: none"> Indoor High Performance Vehicle 	<ul style="list-style-type: none"> Outdoor High Reliability 	<ul style="list-style-type: none"> Indoor General purpose 	<ul style="list-style-type: none"> General purpose 	<ul style="list-style-type: none"> Competitive Price Solution 	<ul style="list-style-type: none"> Competitive Price Solution
Customer	LG	LG	Various	Various	On Promotion LG Reviewing	On Promotion LG Reviewing

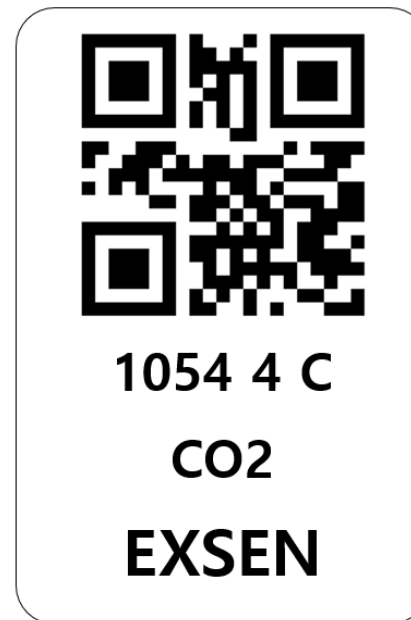
2 modes of RX-9

Freshness (RX-9 Simple mode)



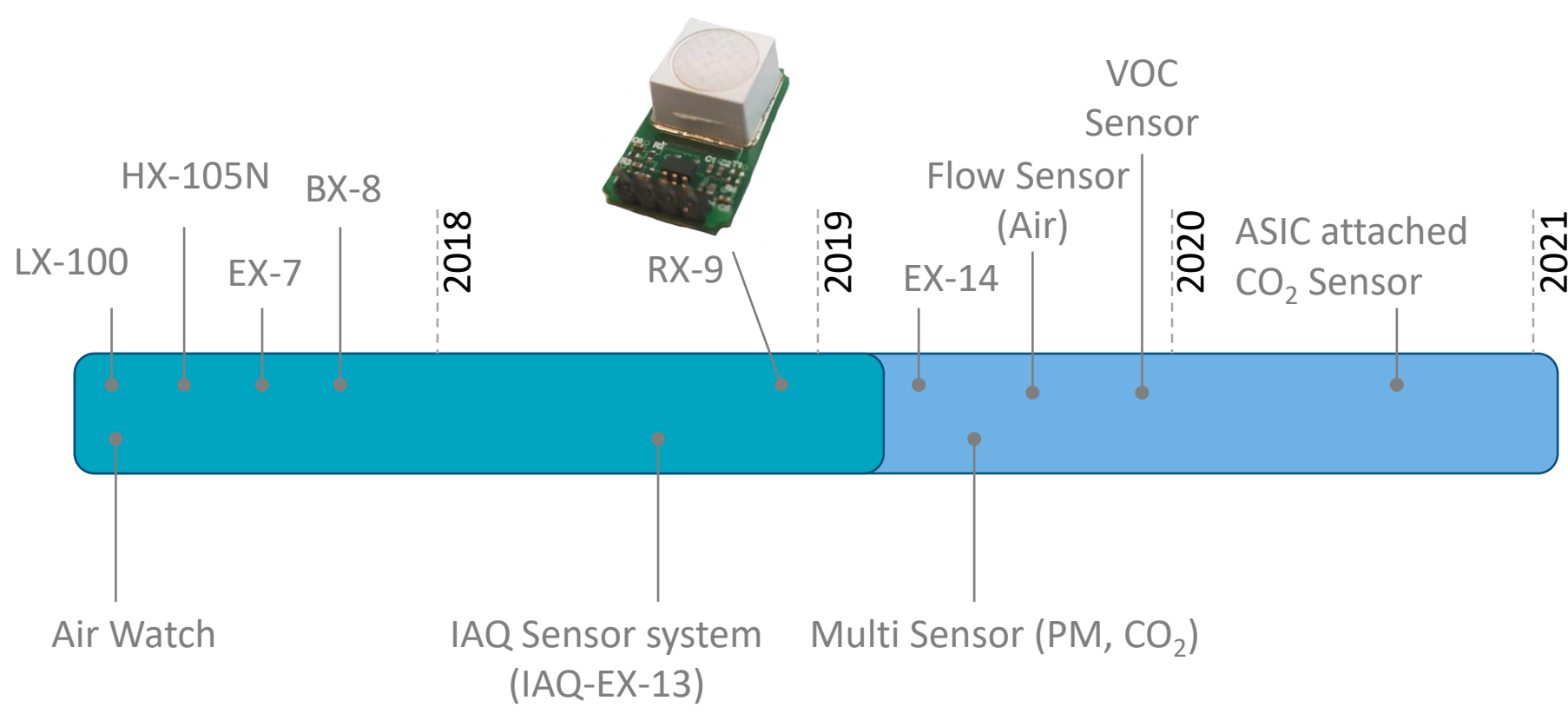
- Simple mode
 - Simple algorithm
 - Intuitive view
 - Very Low-cost price of sensor

CO2 Concentration



- Ppm output mode
 - Algorithm provided
 - Calibration information is on the QR-code
 - Good Accuracy
 - Low-cost

Product Development Road Map



Main Specification (교육용 예시)

Parameters		Min	Typ	Max	Unit
Gas	Target gas	CO ₂			-
Data	Sensor type	Electrochemical			
	Detection range	400-6,200			ppm
	Resolution	1			ppm
	Accuracy	-40 ppm -3% of reading	After Starting 15 min ¹⁾²⁾	+40 ppm +3% of reading	%
		-70 ppm -5% of reading	10 min	+70 ppm +5% o f reading	
		-100 ppm -10% of reading	3 min	+100 ppm +10 % of reading	
Time	Response	2min for 90% for diffusion sampling method			
	Warm-up	1	3	-	min
	Life-time	10			Years
Power	Input	3.2	5	5.1	V
	Current Consump tion	-	0.12	0.15	A
	Warm-up consump tion	0.35	0.6	1	W
Output	Interface connecti ons	UART			
	I2C-ppm	400~6,200			ppm
	UART-ppm	400~6,200			ppm
	State	0: Normal, 1: Warm-up			
	Error	0: Normal, 1: Error			
	Sampling interval		1		Hz
	Connector	SMAW-250-05P			
Ambient	Operating Temp	-40	25	60	°C
	Operating Humidi ty	0	-	95	%
	Storage Temp	-40	25	105	°C
	Storage Humidity	5	-	90	%
Calibration		Not required. and Self mode is ready			-

이산화탄소 감지 범위

400 ~ 6200 ppm

지구 대기: 400~450 ppm

가정집: 400~ 3000 ppm

차량: 400~5000 ppm

정확도

±10%(of Reading)

- 센서 가동 후 48 시간 이후 정확도 측정 가능
- 계속 가동 상태에서는 빠르게 센서 정확도를 측정 가능
- 비가동 방치 상태에서 센서 재 가동시 48시간 이후 정확도 측정 가능(48시간 이내에는 다소 오차가 있는 값을 출력함)

Warm-up

1~3분

- 주변의 이산화탄소를 측정하기 위해서 센서를 가열해야 하는데, 가열하는데 걸리는 최소 시간
- Warm-up 이후 출력값 사용

소모 전력

120~150 mA, 0.6W~1W

- 센서 연속 구동시 약 0.6~1W 정도의 전력 소모함
- 배터리 구동 시스템은 배터리 용량 산정에 참고해야 함
- 연속 구동을 권장함

지원 통신

I2C, UART, AVO

- 제품별로 지원하는 통신 규격이 다르니, 고객 요구 사항에 맞춰 제안해야 함

Main Specification (교육용 예시)

Parameters		Min	Typ	Max	Unit
Gas	Target gas	CO ₂			-
Data	Sensor type	Electrochemical			
	Detection range	400-6,200			ppm
	Resolution	1			ppm
	Accuracy	-40 ppm -3% of reading	After Starting 15 min ¹⁾²⁾	+40 ppm +3% of reading	%
		-70 ppm -5% of reading	10 min	+70 ppm +5% o f reading	
		-100 ppm -10% of reading	3 min	+100 ppm +10 % of reading	
Time	Response	2min for 90% for diffusion sampling method			
	Warm-up	1	3	-	min
	Life-time	10			Years
Power	Input	3.2	5	5.1	V
	Current Consump tion	-	0.12	0.15	A
	Warm-up consump tion	0.35	0.6	1	W
Output	Interface connecti ons	UART			
	I2C-ppm	400~6,200			ppm
	UART-ppm	400~6,200			ppm
	State	0: Normal, 1:Warm-up			
	Error	0:Normal, 1:Error			
	Sampling interval		1		Hz
	Connector	SMAW-250-05P			
Ambient	Operating Temp	-40	25	60	°C
	Operating Humidi ty	0	-	95	%
	Storage Temp	-40	25	105	°C
	Storage Humidity	5	-	90	%
Calibration		Not required. and Self mode is ready			-

측정 간격 1초

- UART: 초당 1회씩 데이터 출력
- I2C: I2C command 발생시마다 업데이트/출력
- AVO: 실시간 업데이트/출력

커넥터

- 커넥터 가격 50원 이하, >MOQ 수량에 대해 커넥터
삽입/납품 가능
- 커넥터 삽입 후 반품 불가
 - 일반적인 커넥터 사양만 가능(특수 커넥터 불가)

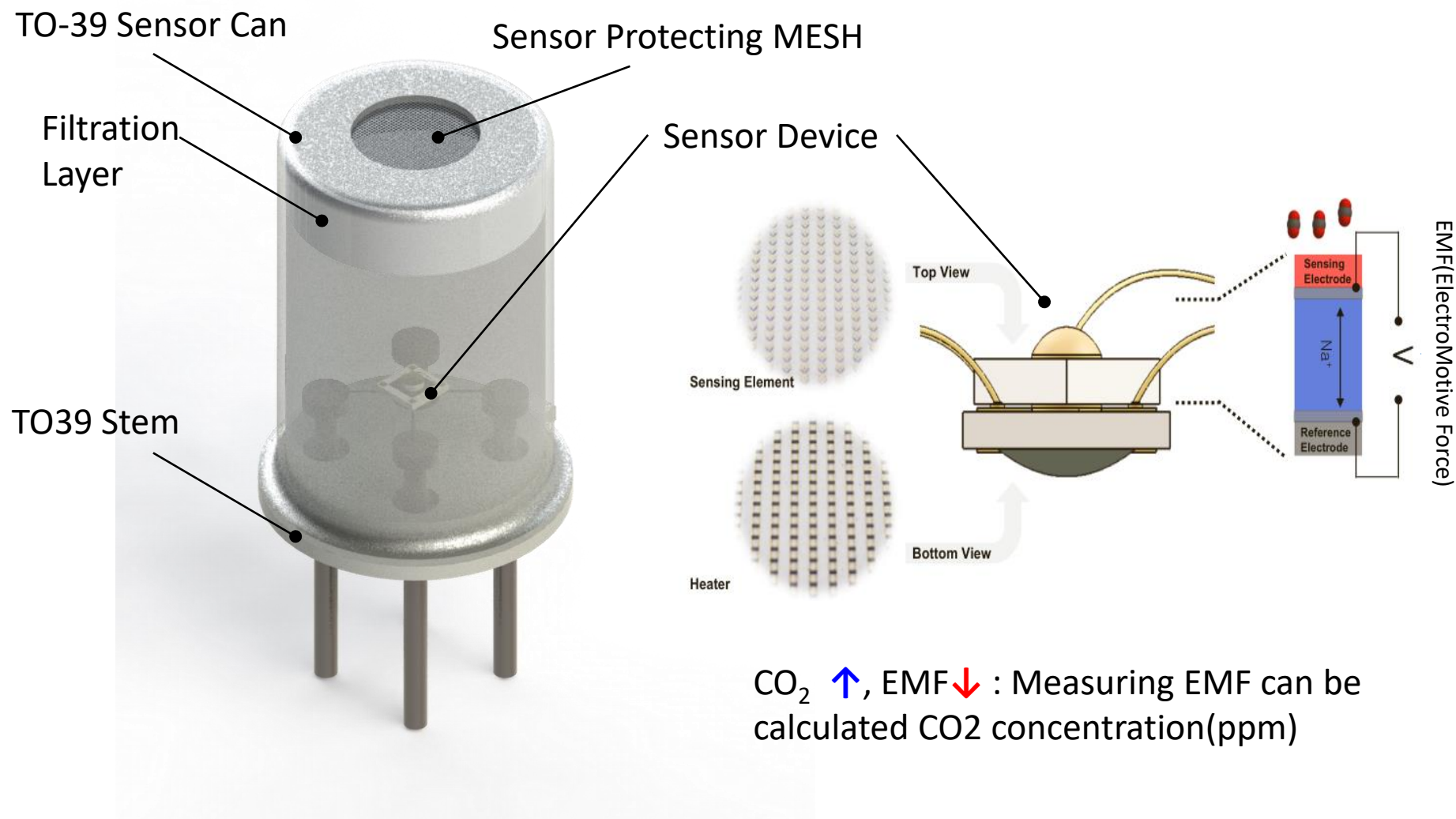
사용 온도/ 보관 온도

- 사용 가능한 온도: 센서가 구동 중에 기능을 상
실하지 않는 온도
- 보관 온도: 센서를 해당 온도에 보관하여도 센서
가 기능을 상실하지 않는 온도
- 정확도 측정 온도: 센서의 정확도는 25도씨50%
이하에서 구동한 경우에 적용됨

자동 교정(Auto Calibration Logic)

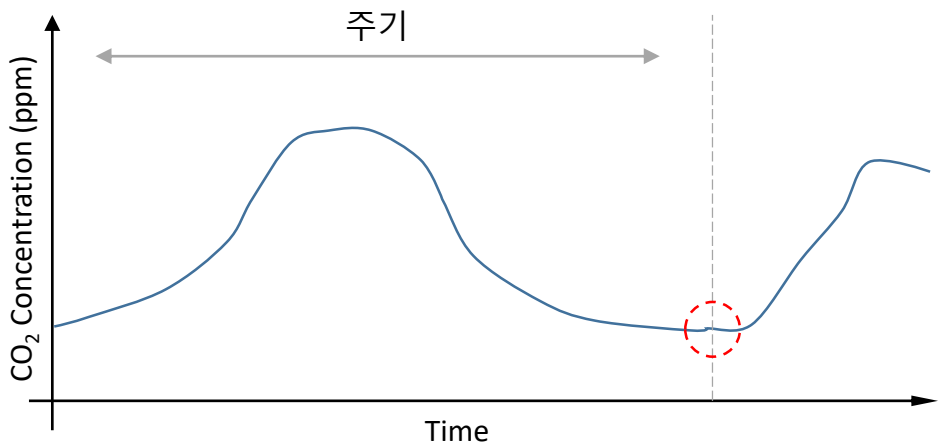
- 모든 센서는 시간이 경과에 따라 센서 고유의 값
이 변화함
- 엑센의 센서는 자동 교정 기능에 의해 주기적으
로 센서의 값을 교정함
- 모듈로 판매되는 제품(Rx-9 제외)은 모두 자동
교정 기능이 구현되어 있음

Sensor structure



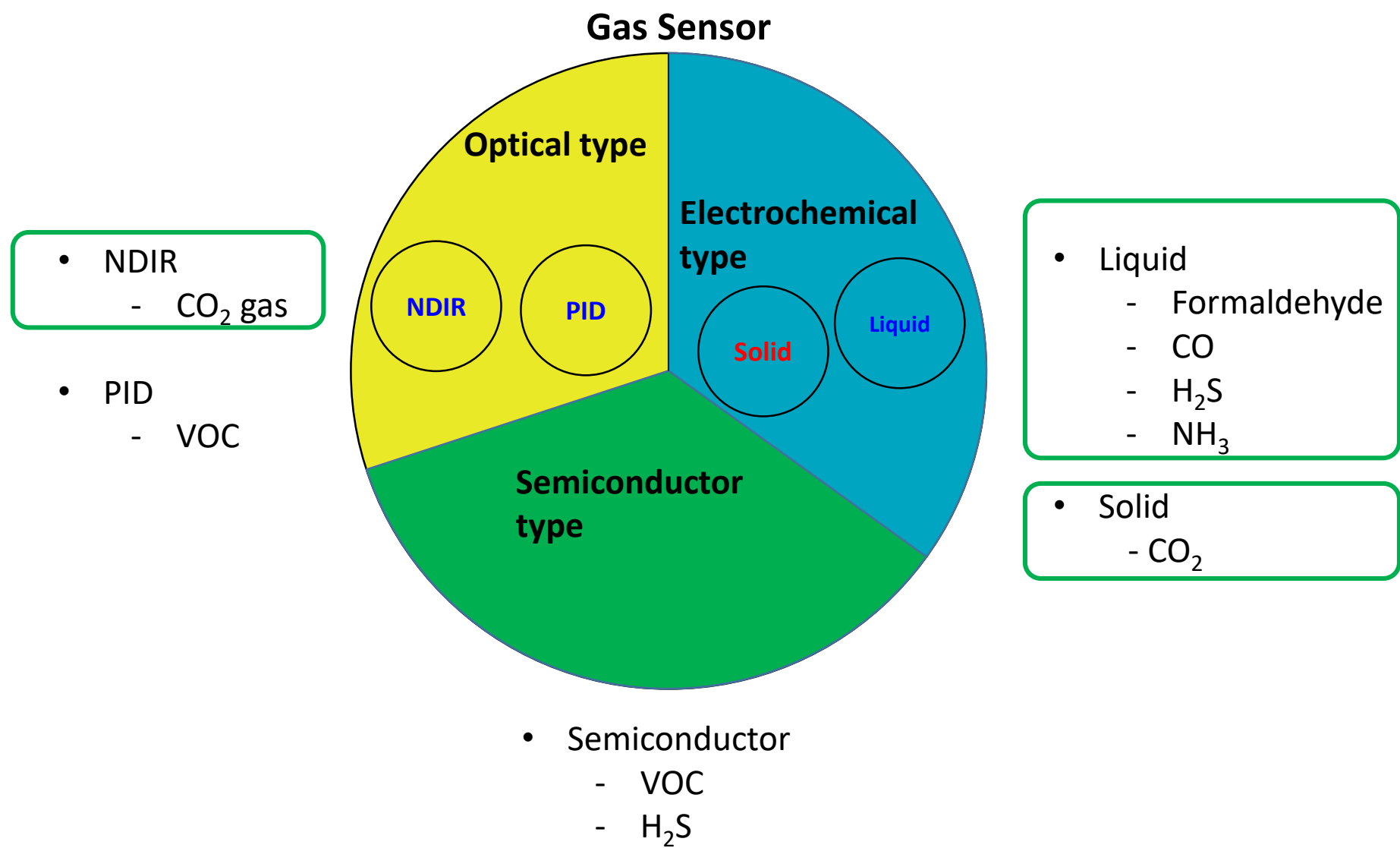
Auto Calibration Logic

- 모든 센서는 출력값이 시간 변화에 따라 변화함
- 이를 보정하기 위해 계측기는 주기적으로 보정을 진행
- 엑센의 이산화탄소 센서는 주기적으로 센서의 출력농도를 파악하여 센서를 자동 보정하기 때문에, 설치 후에 교정 혹은 교체가 필요 없음



- 1주기 내 최저 농도를 기록함
- 지구 대기 보다 낮은 이산화탄소 농도는 자연적으로 발생할 수 없음
- 지구 대기는 약 400 ppm
- 1주기 내 최저 농도를 400 ppm으로 환산
- 해당 주기 종료 후, 새로운 주기가 시작될 때 적용
- 엑센 제품의 자동 보정 주기는 1~2일(어플리케이션마다 다름)
- 해외 경쟁사의 자동 보정 주기는 4~5주

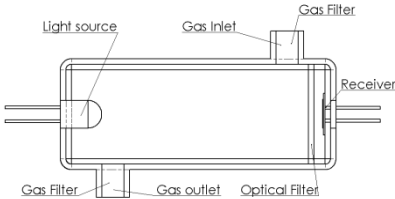
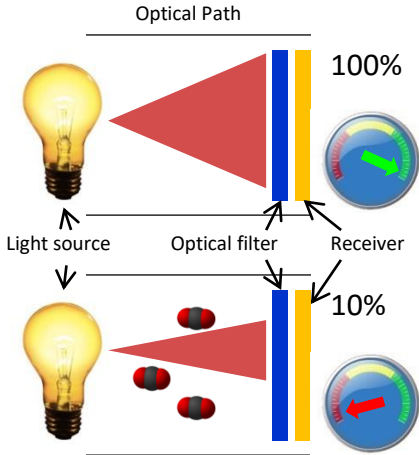
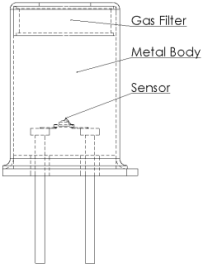
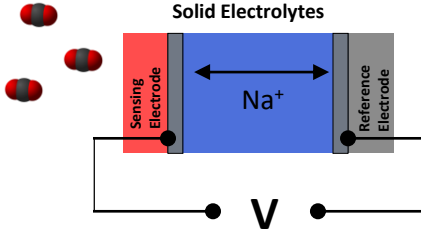
Q: 1주기 내에 상시 높은 농도가 계속해서 유지되는 경우에는 어떻게 작동하는지?
A: 1주기 내 낮은 농도에 노출되지 않는다면, 높은 농도의 값을 지구 대기 농도인 400ppm으로 계산합니다. 이 부분이 문제가 될 수 있지만, 센서가 설치되는 어플리케이션에 따라 주기를 조절하여 해결이 가능합니다. 또한, 이에 의해 센서 출력값이 잘못 출력되더라도 단 한번이라도 깨끗한 공기(바깥공기)에 노출이 되면 바로 정상값으로 출력이 가능합니다.



- 엑센의 고체 전기화학식 센서는 기존의 MOS(반도체식) 센서와 다른 센서입니다.

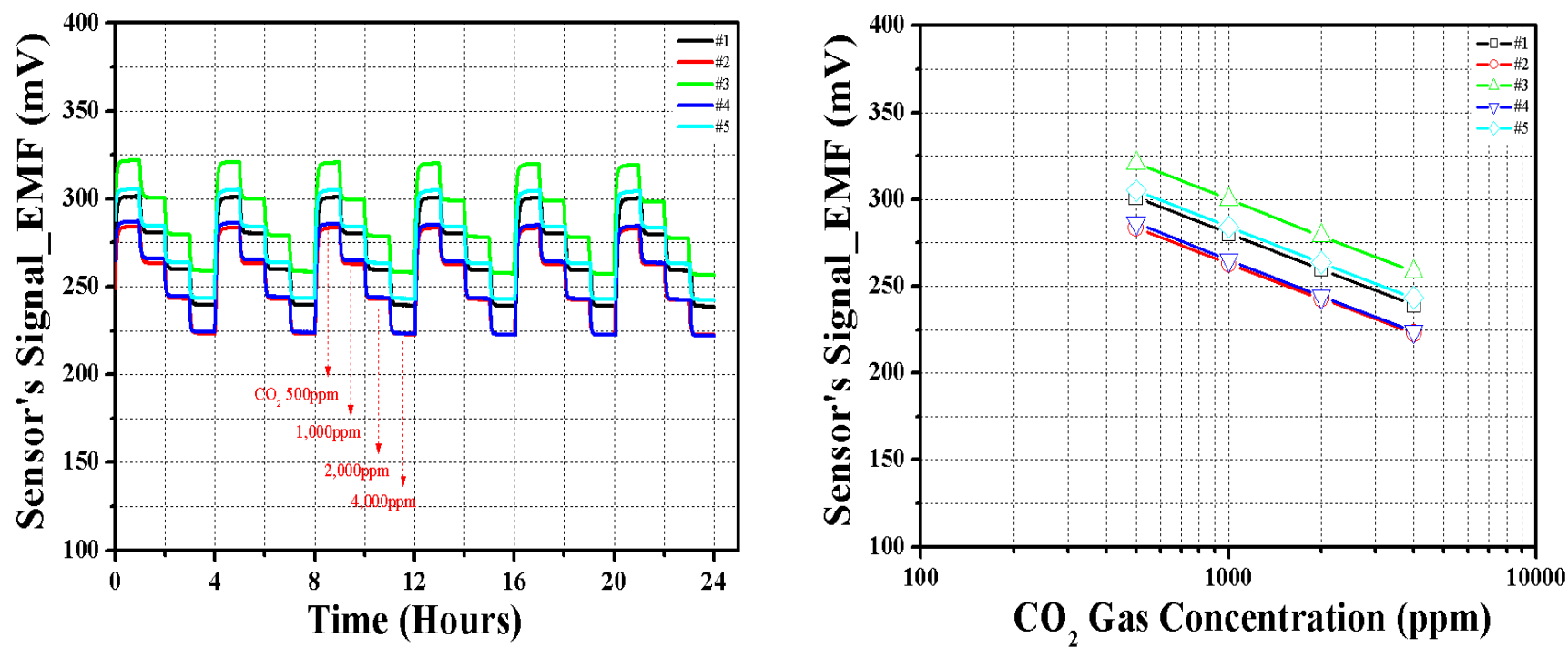
- MOS 센서 대비 우수한 성능/수명을 보유하고 있습니다. (>10 year)

- 주기적인 교체가 필요한 액체 전기화학식 센서와는 달리 엑센의 고체 전기화학식 센서는 교체 없이 사용이 가능합니다.

Type	Structure	Operating principle	
광학식 (NDIR, Non dispersive Infra ray)	<div></div> <ul style="list-style-type: none">• Main Components<ul style="list-style-type: none">- Light source (Lamp)- Optical Filter- Receiver- Optical Path	<div></div> <ul style="list-style-type: none">• CO₂ Gas Absorption Wavelength = 4,260 nm• 4,260 nm Selectivity : Optical Filter & Light source Combination• Receiver Intensity (4,260 nm) $\propto 1/\text{CO}_2$ Concentration• Optical Path length \propto resolution	
전기화학식 (Electro-chemical)	<div></div> <ul style="list-style-type: none">• Main Components<ul style="list-style-type: none">- Sensor- Gas Filter	<div></div> <ul style="list-style-type: none">• Na⁺ ion movement(@Electrolyte) \rightarrow Sensing Electrode• Voltage between Sensing Electrode and Reference Electrode• Voltage(mV) $\propto 1/\text{CO}_2$ Concentration	

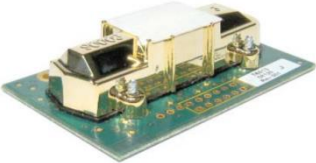

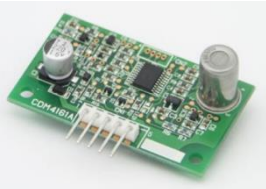
Characteristics according to CO₂ Concentration Change

As shown by Figure 1, the RX-9 has good response and repeatability to CO₂ gas concentration change and exhibits nearly the same characteristics per sample. RX-9 exhibits a very good liner relationship between Sensor's Signal (EMF) and CO₂ gas concentration on a logarithmic scale.



[Figure 1] Evaluation of sensor performance according to the CO₂ Concentration change.

COMPETING TECH

		NDIR		Electrochemical		Electrochemical
Sensor structure						
Competitor		Global		KOREA EXSEN (HX-105N)		JAPAN F COMPANY CDM4161A
Dimension		44.5 x 35 (mm ²)		35 x 21 (mm ²) Smallest		45 x 26 (mm ²)
Operating Temp		-5~60°C (S company) 0~50°C (E company) -25~55°C (G company) -40~60°C (E2 company) -30~80°C (N company)		-40~85°C (HX-105N) -20~60°C (EX-7, Rx-9)		0~50°C (F company)
Reliability	High Temp	Good	<	Very Good	=	Very Good
	High Humi	Good	<	Very Good	>	Good
	Particle resistivity	Bad	<	Excellent	=	Excellent
	Life Time	10 years	=	10 years	=	10 years
Resolution		1 ppm	=	1 ppm	=	1ppm
Cost		100%	<	<50%	>	100%

Comparison of response time with NDIR Sensor

Figure 5 compares the CO₂ output of the RX-9 mounted on the evaluation board with the NDIR sensor. As can be seen, the response and recovery time for CO₂ gas are almost similar.

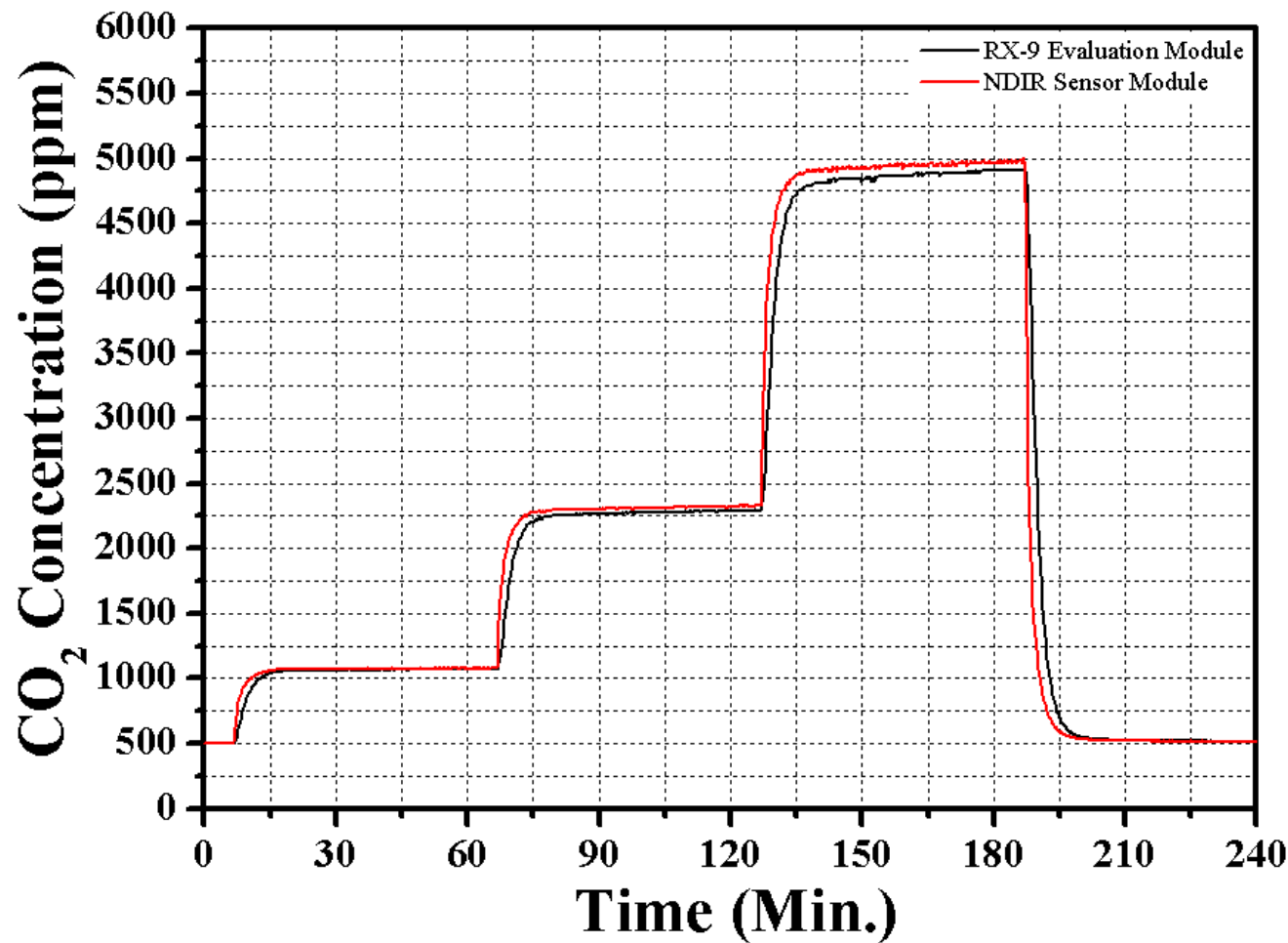
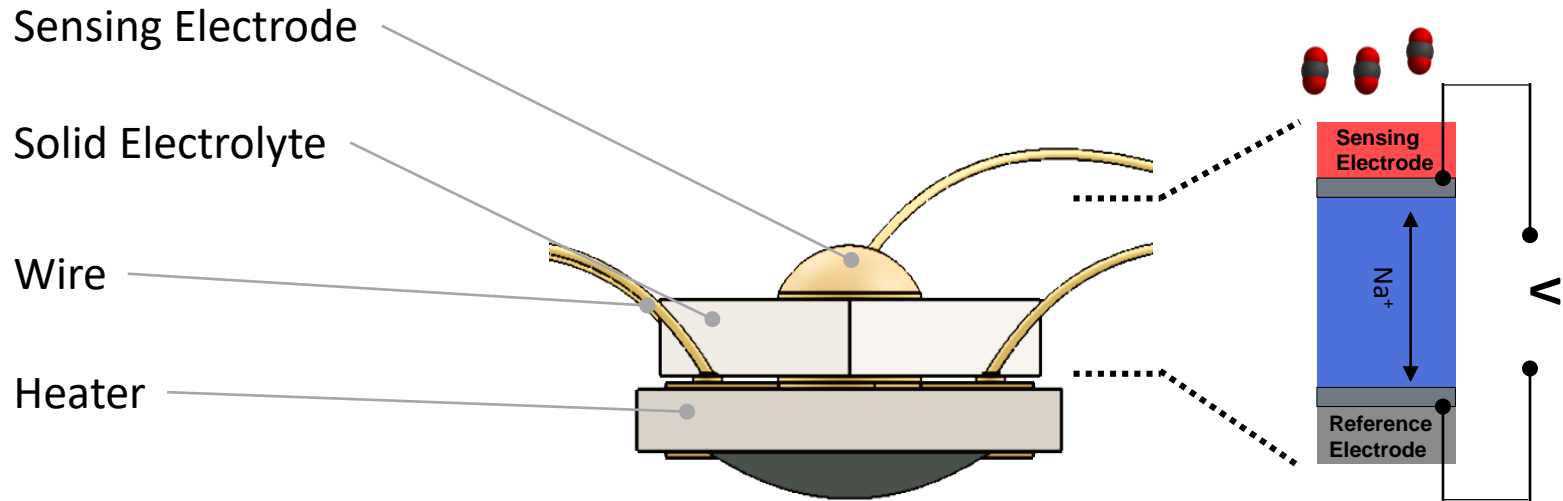


Figure 5. Evaluation of gas response and recovery characteristics.

Type	특징	장점	단점
Liquid Electrolyte	<ul style="list-style-type: none">전해질 구성: 액체산 혹은 염기성의 액체상온 구동 가능	<ul style="list-style-type: none">다양한 가스 감지 가능상온 구동 = 낮은 전력 소모	<ul style="list-style-type: none">짧은 수명, 주기적인 센서 교체 필요고온 노출시 전해질 증발노출되는 가스의 농도에 따라 수명이 결정됨, 고농도 노출시 급격한 수명 저하
Solid Electrolyte	<ul style="list-style-type: none">전해질 구성: 고체히터 필요Carbonate 계열	<ul style="list-style-type: none">높은 신뢰성긴 수명	<ul style="list-style-type: none">상대적으로 높은 전력 소모

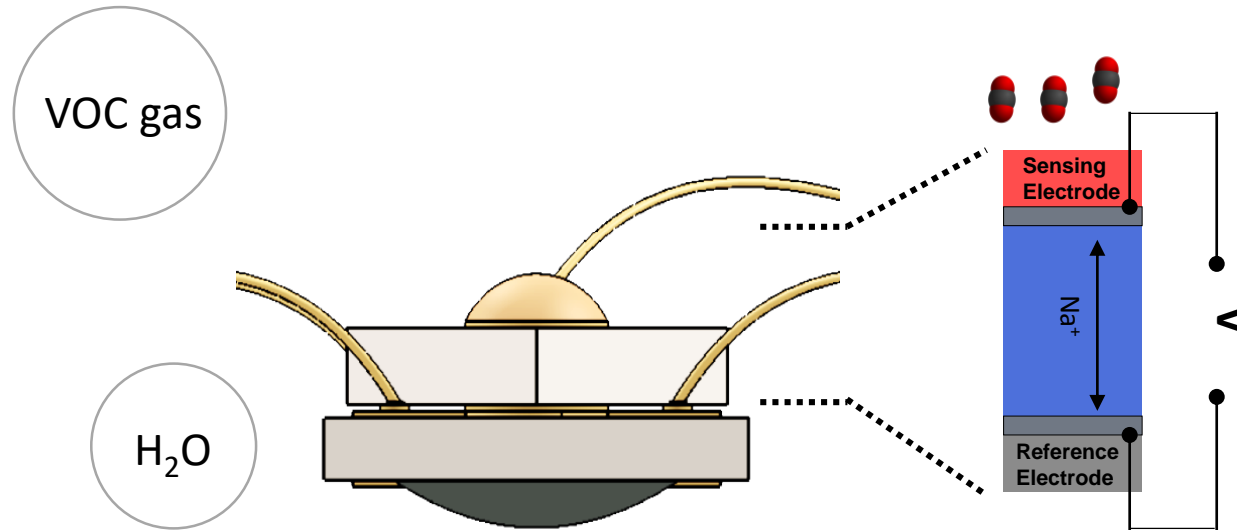
Warm-up



To sense carbon dioxide gas with solid electrolyte sensor, sensor should be heated about 400 Celsius degree. So it takes few minutes to heat sensor.

Temperature of heater core is very high. But the Surface of sensor package is warm ,50~70 Celsius degree.

Storage Condition



Under non-operating, VOC gas and H₂O gas could adsorb to sensor. Because the sensor is ceramics it has very many pores can keep the gas. So when operate the sensor again. It may need the time to heat to remove the gas from sensor. After the burning the gas on the sensor, sensor will be operated properly. It takes time about 1 or 2 days to burn it. so storage the sensor under dry and clean atmosphere.

Expected Life-Time of EXSEN CO₂ Sensor

Acceleration test for predicting the lifetime of a solid electrochemical sensor is a method to confirm the degradation point of the sensor output value (EMF) according to the heater temperature. As shown in the figure 6, when the heater temperature increases by about 50 degrees, the time to maintain the sensor stability is shortened by 10 times.

At a heater temperature of 500°C, a stable sensor output value was measured for about 80 days. Based on this, it is used as a basis to judge the life time of about 800 days for a heater temperature of 450°C and about 8,000 days (20 years) for a temperature of 400°C.

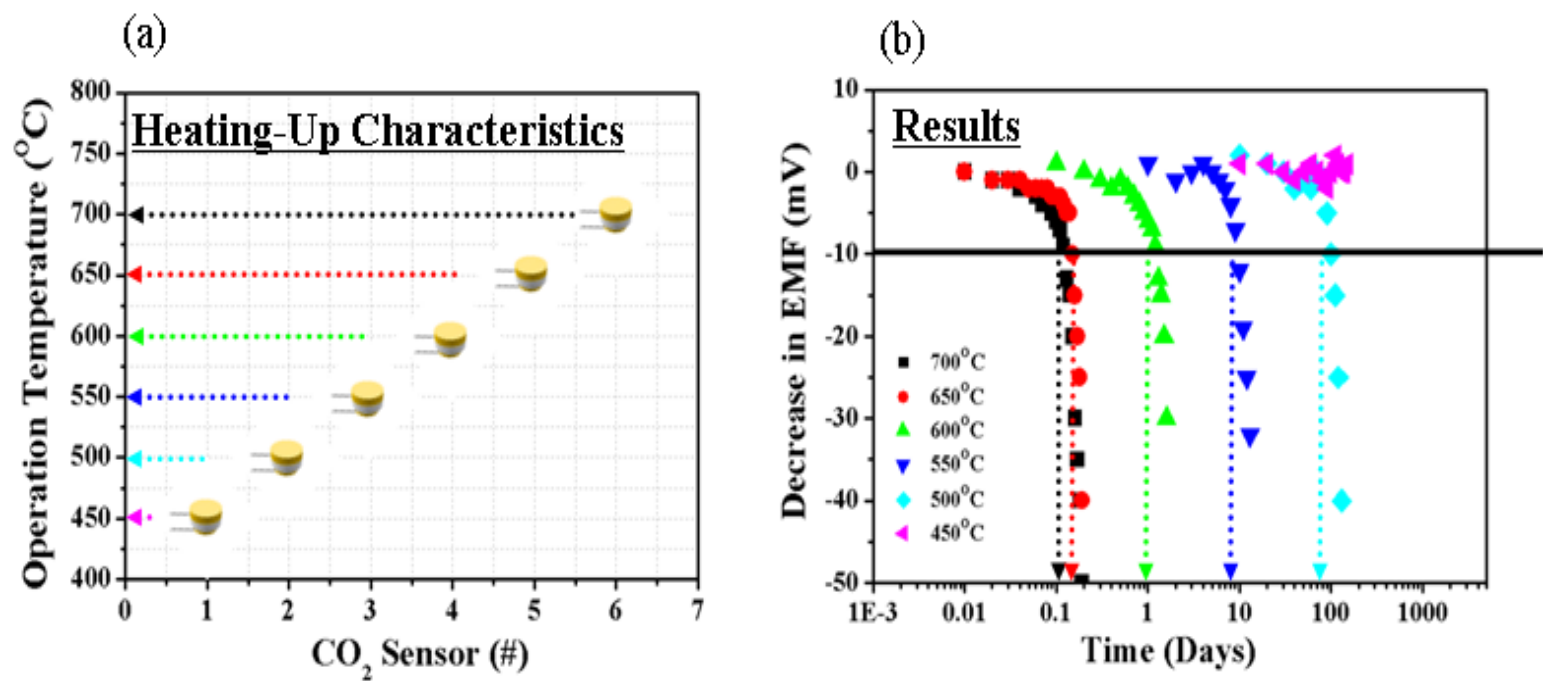


Figure 5. Acceleration test for sensor life prediction

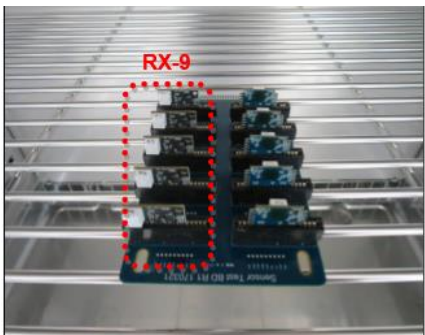
Reliability Test

No	Sensor Characteristics	Test conditions and evaluation method	Criteria and Results	Page
1	High Temperature/ Humidity Test	<ul style="list-style-type: none"> ■ Non-Operation Test : Exposure for 500 hours in 85°C/85%R.H. → Performance Determination <ul style="list-style-type: none"> I. Perform aging at room temperature, humidity, and atmospheric CO₂ concentration II. After the self-compensation cycle, standard carbon dioxide gas is injected to determine accuracy. 	Within ±10% of standard Gas (Pass)	23
2	Temperature Test	<ul style="list-style-type: none"> ■ High Temperature Operation Test : Exposure for 240 hours in 85°C ■ High Temperature Non-Operation Test : Exposure for 240 hours in 85°C ■ Low Temperature Operation Test : Exposure for 240 hours in -40°C ■ Low Temperature Non-Operation Test : Exposure for 240 hours in -40°C → Performance Determination : Same as high temperature and high humidity test 	Within ±10% of standard Gas (Pass)	24-27
3	Humidity Test	<ul style="list-style-type: none"> ■ 1cycle : 95% R.H. 8hr-> 5% R.H. 2hr, 10times in total → Performance Determination : Same as high temperature and high humidity test 	Within ±10% of standard Gas (Pass)	28-29
4	Heat Cycle Test	<ul style="list-style-type: none"> ■ 1 cycle : -40°C 30min, 85°C 30min, 300times in total → Performance Determination : Same as high temperature and high humidity test 	Within ±10% of standard Gas (Pass)	30
5	Vibration/Shock Test	<ul style="list-style-type: none"> ■ Automotive parts test conditions (KSR 1034) → Performance Determination Visual inspection : Mechanical damage such as deformation, separation, crack, loosening of screw, etc. Performance check : LED on check 	Visual & Operation Inspection (Pass)	31-32
6	ESD Test	<ul style="list-style-type: none"> ■ Apply 4kV static positive / negative voltage to the input and output terminals 10 times → Performance Determination : Same as vibration test 	Visual & Operation Inspection (Pass)	33
7	Accuracy Test	<ul style="list-style-type: none"> ■ Accuracy Test when standard CO₂ concentration changes from 500ppm to 5,000ppm. 	Within ±10% of standard Gas (Pass)	34-35

High Temperature/Humidity Test Results (HTHH NO-BIAS)

RX-9 Sensor maintains stable characteristics even if the sensor is used in high temperature and humidity conditions.

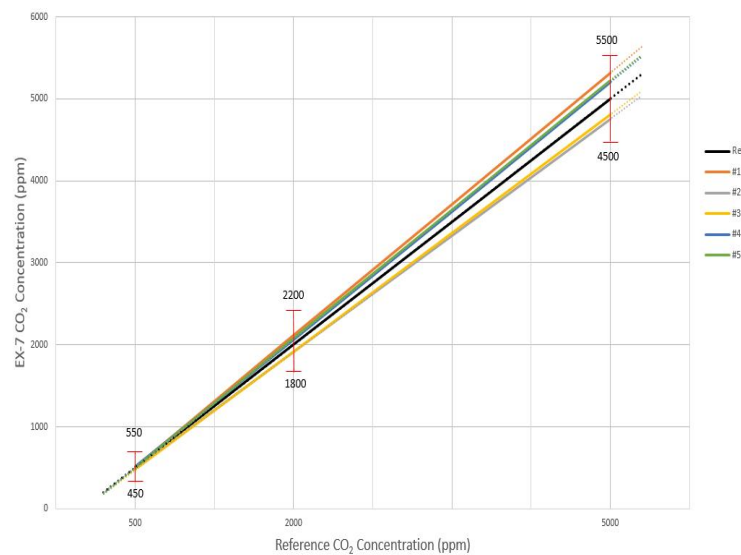
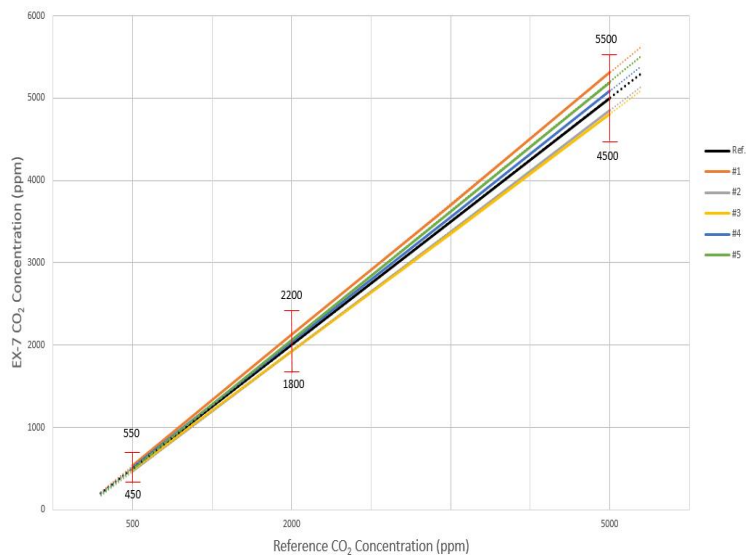
Test Condition & Equipment



- ▶ Test temperature : **85 °C**
- ▶ Test humidity : **85% R.H.**
- ▶ Test time : **502 h**
- ▶ Check point : Before the test, After the test
- ▶ Status of product : ① Un-packaged product
② Non-operation
- ▶ Test voltage : DC 5 V
- ▶ Sample quantity : 5 EA

PASS

Test Results (Before & After)



High Temperature Test Results _ Temp. of Operation (HT Bias)

Stable CO₂ Sensitivity can be expected even if RX-9 Sensor is exposed to extremely high temperature.

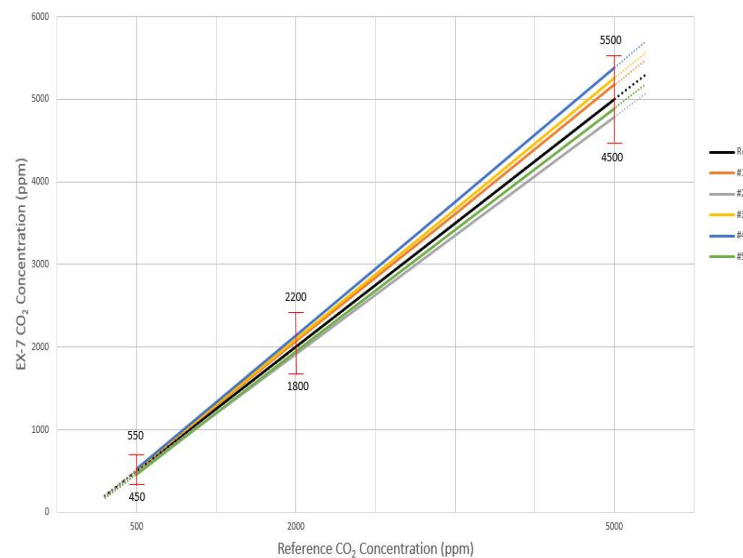
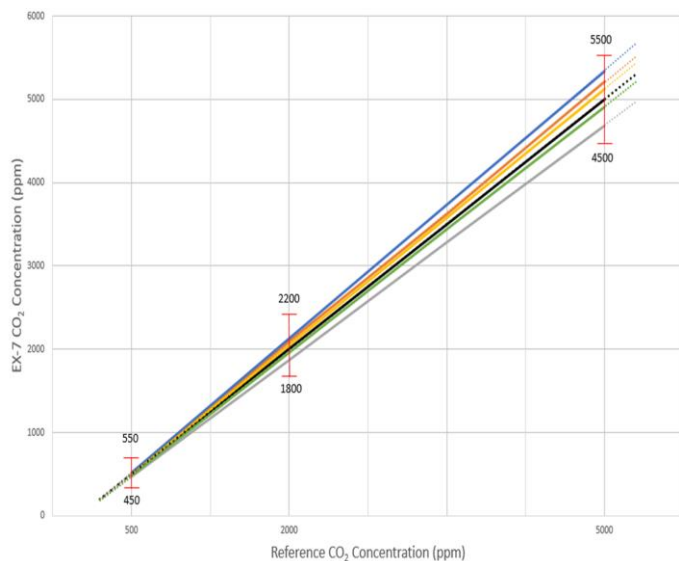
Test Condition & Equipment



- ▶ Test temperature : **85°C**
- ▶ Test time : **242 h**
- ▶ Check point : Before the test, After the test
- ▶ Status of product : ① Un-packaged product
② Operation
- ▶ Test voltage : DC 5 V
- ▶ Sample quantity : 5 EA

PASS

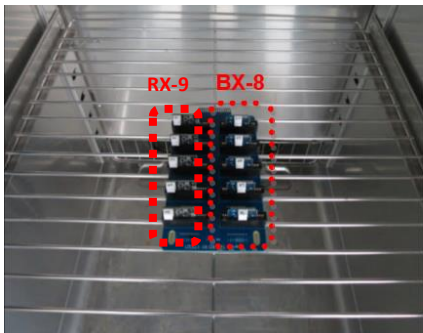
Test Results (Before & After)



High Temperature Test Results _ Temp. of Storage (HT No-Bias)

Stable CO₂ Sensitivity can be expected even if RX-9 Sensor is exposed to extremely high temperature.

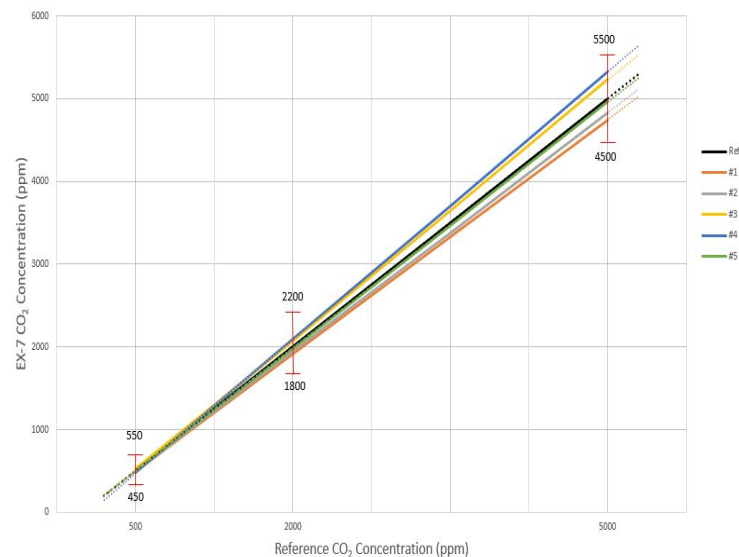
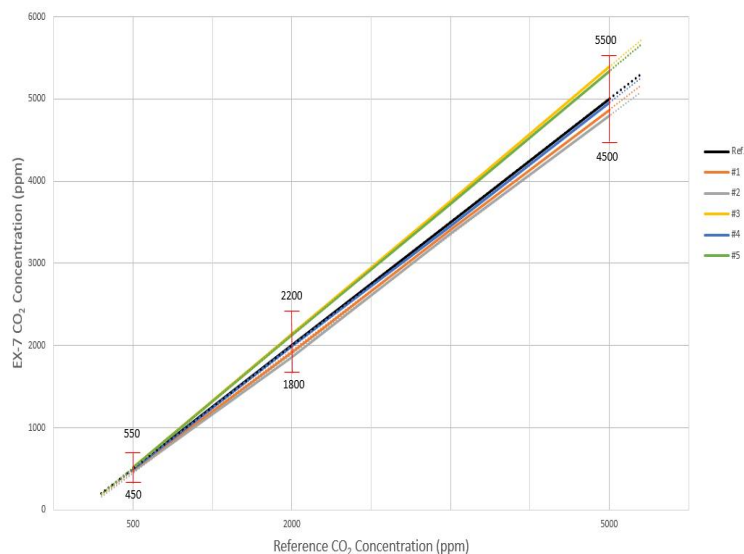
Test Condition & Equipment



- ▶ Test temperature : **120°C**
- ▶ Test time : **243 h 10min**
- ▶ Check point : Before the test, After the test
- ▶ Status of product : ① Un-packaged product
② Non-Operation
- ▶ Test voltage : DC 5 V
- ▶ Sample quantity : 5 EA

PASS

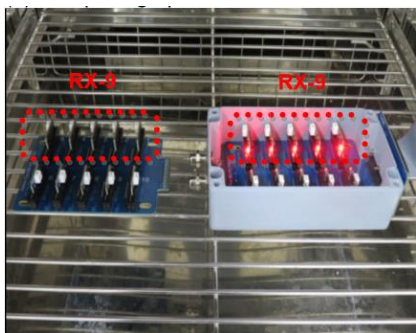
Test Results (Before & After)



Low Temperature Test Results _ Temp. of Operation (LT Bias)

Stable CO₂ Sensitivity can be expected even if RX-9 Sensor is exposed to extremely low temperature.

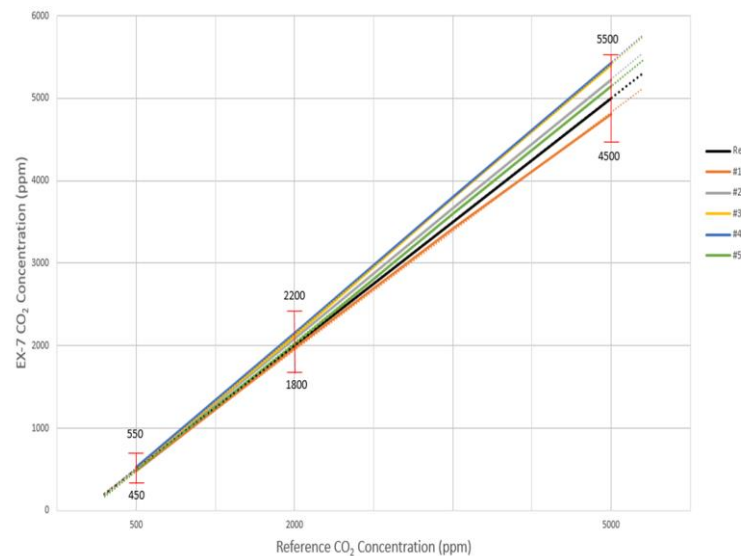
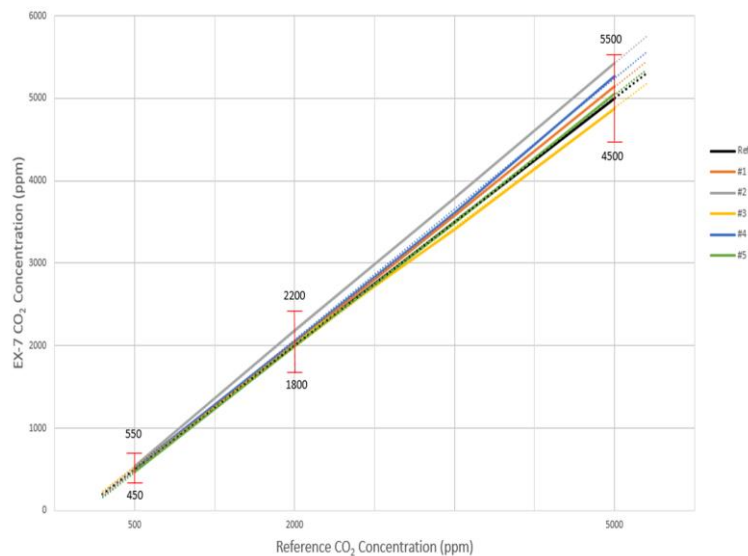
Test Condition & Equipment



- ▶ Test temperature : **-40°C**
- ▶ Test time : **242 h 10min**
- ▶ Check point : Before the test, After the test
- ▶ Status of product : ① Un-packaged product
② Operation
- ▶ Test voltage : DC 5 V
- ▶ Sample quantity : 5 EA

PASS

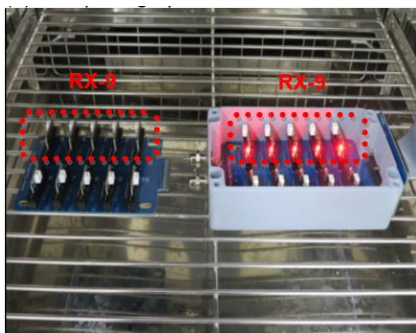
Test Results (Before & After)



Low Temperature Test Results _ Temp. of Storage (LT No-Bias)

Stable CO₂ Sensitivity can be expected even if RX-9 Sensor is exposed to extremely low temperature.

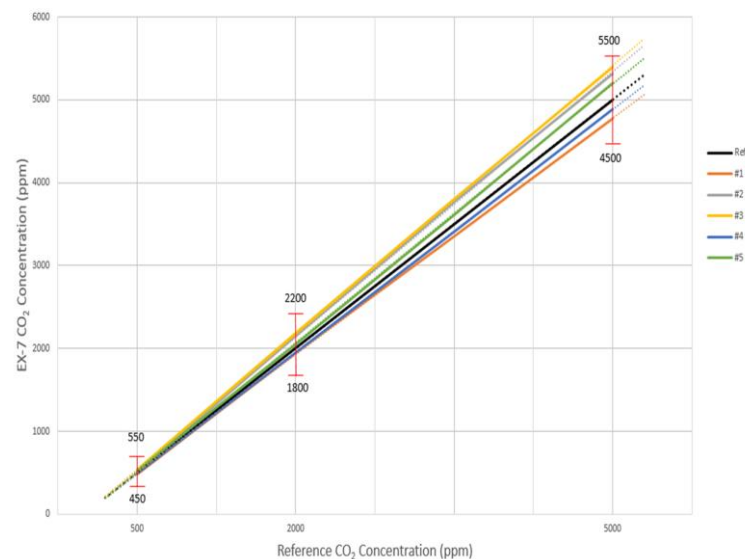
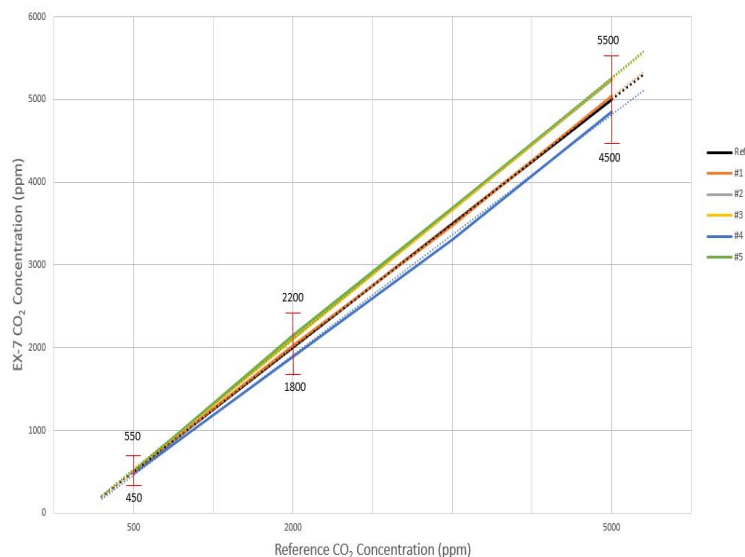
Test Condition & Equipment



- ▶ Test temperature : **-40 °C**
- ▶ Test time : **242 h 10min**
- ▶ Check point : Before the test, After the test
- ▶ Status of product : ① Un-packaged product
② Non-Operation
- ▶ Test voltage : DC 5 V
- ▶ Sample quantity : 5 EA

PASS

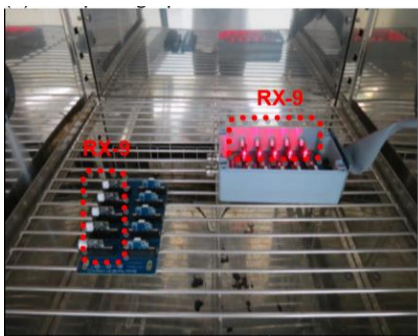
Test Results (Before & After)



Humidity Test Results _ Humidity of Operation (RT HH Bias)

There is almost no influence by humidity on the sensitivity characteristics of RX-9 Sensors.

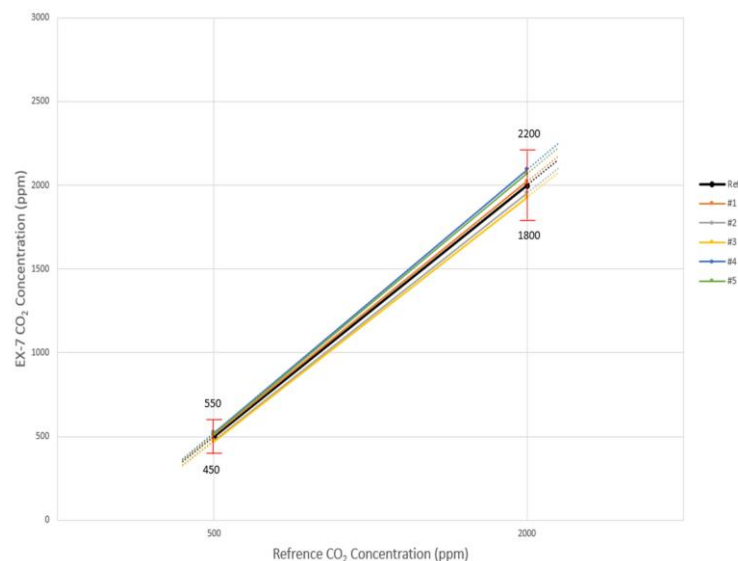
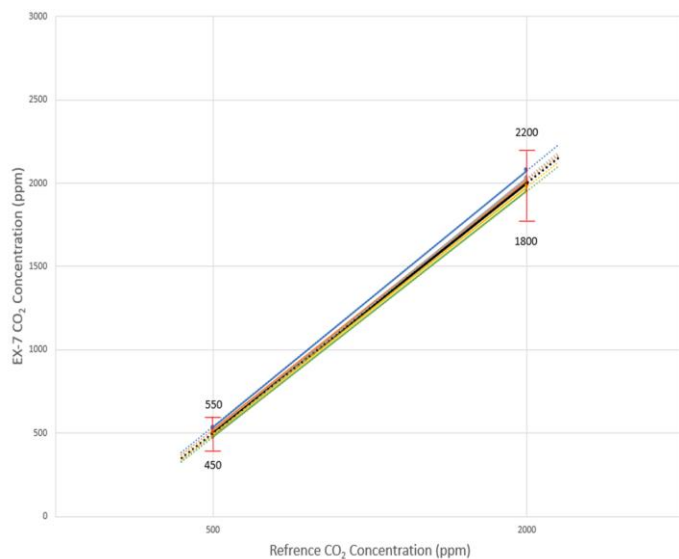
Test Condition & Equipment



- ▶ Test Temperature : **25 °C**
- ▶ Test Humidity : **0~95% R.H.**
- ▶ Test Cycle : 10cycles
- ▶ Test Time : **150h**
- ▶ Check point : Before the test, After the test
- ▶ Status of product : ① Un-packaged product
② Operation
- ▶ Test voltage : DC 5 V
- ▶ Sample quantity : 5 EA

PASS

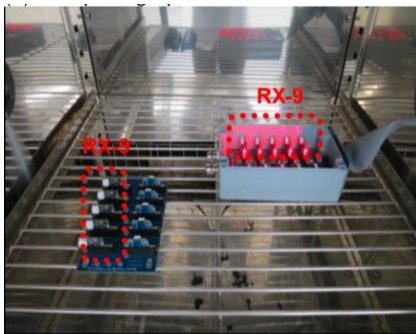
Test Results (Before & After)



Humidity Test Results _ Humidity of Storage (RTHH No-Bias)

There is almost no influence by humidity on the sensitivity characteristics of RX-9 Sensor.

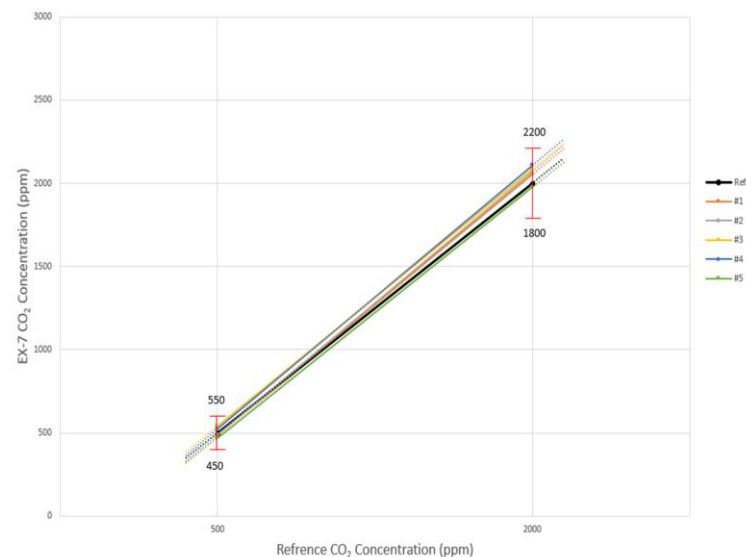
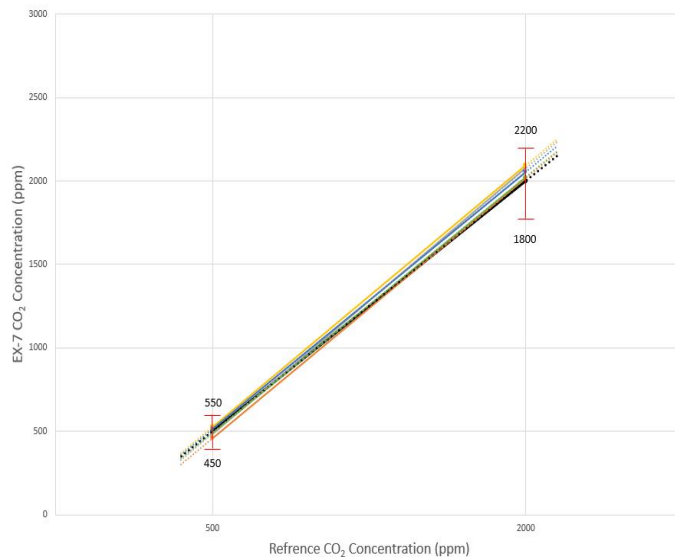
Test Condition & Equipment



- ▶ Test Temperature : **25 °C**
- ▶ Test Humidity : **10~95% R.H.**
- ▶ Test Cycle : 10cycles
- ▶ Test Time : **150h**
- ▶ Check point : Before the test, After the test
- ▶ Status of product : ① Un-packaged product
② Non-Operation
- ▶ Test voltage : DC 5 V
- ▶ Sample quantity : 5 EA

PASS

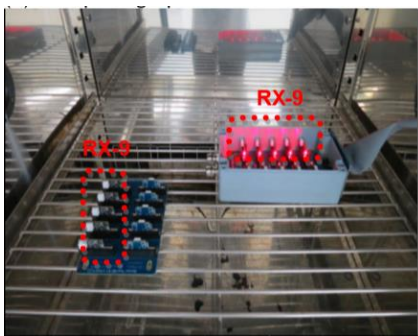
Test Results (Before & After)



Heat Cycle Test Results (Thermal Shock No-Bias)

RX-9 Sensor has sufficient durability against the severity of heat cycle conditions.

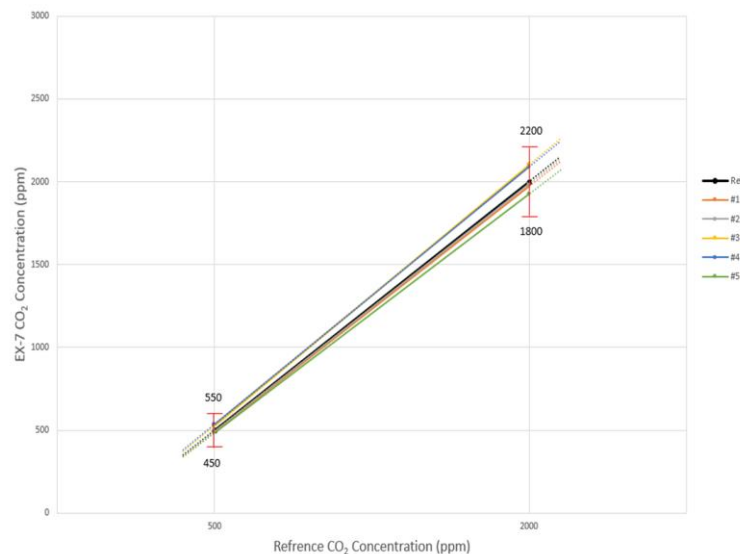
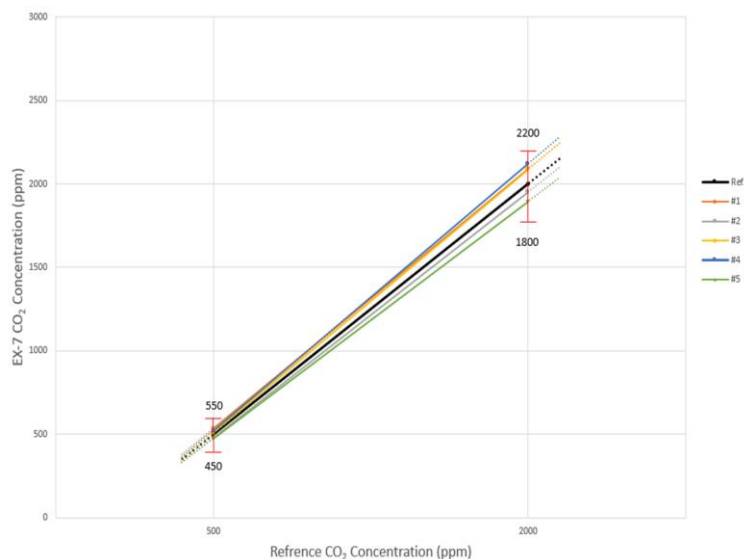
Test Condition & Equipment



- ▶ Test Temperature : **(-40 ~ 85) °C**
- ▶ Test Cycle : **100cycles**
- ▶ Test Time : **100h**
- ▶ Check point : Before the test, After the test
- ▶ Status of product : ① Un-packaged product
② Non-Operation
- ▶ Test voltage : DC 5 V
- ▶ Sample quantity : 5 EA

PASS


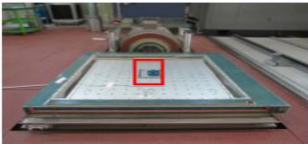

Test Results (Before & After)



Vibration Test Results

RX-9 Sensor operate without damage even under severe vibration conditions.

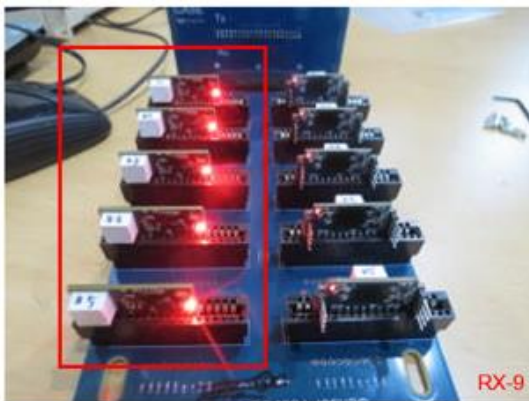
Test Condition & Equipment

Test axis	Test photograph
Vertical (Z)	
Transverse (X)	
Longitudinal (Y)	

- ▶ Test Type : Sweep sine
- ▶ Frequency : (10 ~ 200) Hz
- ▶ Accelerometer : 44.1 m/s²
- ▶ Sweep rate : 5 min/sweep
- ▶ Sweep cycles : Z-24 cycles(48sweeps), X,Y-12cycles(24sweeps)
- ▶ Test time : 8 h in total (Z – 4 h, X,Y – 2 h)
- ▶ Test axis : Vertical (Z), Transverse (X), Longitudinal (Y)
- ▶ Check time : Before, After the test
- ▶ Sample condition : Unpackaged/Non operation
- ▶ Sample quantity : 5 EA

PASS

Test Results



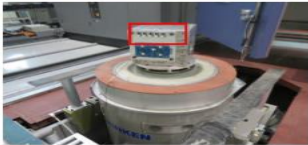


Check Item	Test Results
Visual inspection - Mechanical damage such as deformation, separation, crack, loosening of screw, etc.	No abnormal was found
Performance check – LED on check	Pass

Shock Test Results

RX-9 Sensor operate without damage even under severe shock conditions.

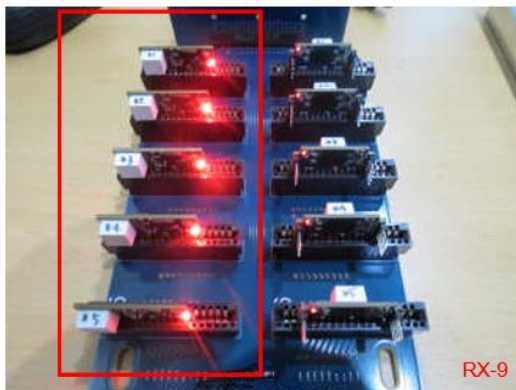
Test Condition & Equipment

Test axis	Test photograph
Vertical (Z)	
Transverse (X)	
Longitudinal (Y)	

- ▶ Test Type : Half sine
- ▶ Accelerometer : 490 m/s²
- ▶ Duration : 11 ms
- ▶ Number of shocks : 18 times in total (±3 times in each axis)
- ▶ Test axis : Vertical (Z), Transverse (X), Longitudinal (Y)
- ▶ Check time : After the test
- ▶ Sample condition : Unpackaged/Non operation
- ▶ Sample quantity : 5 EA

PASS

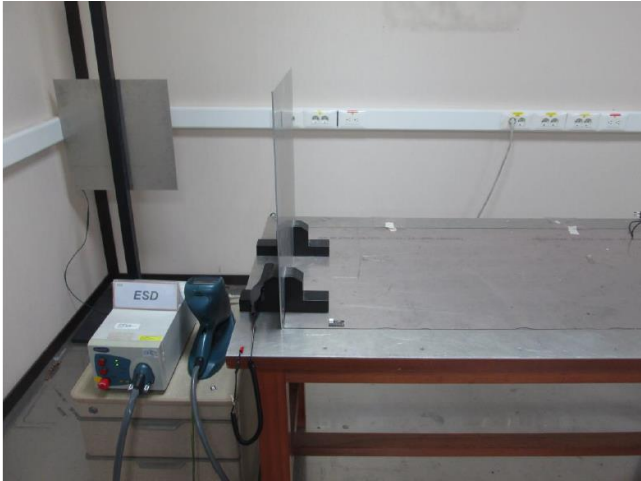
Test Results



Check Item	Test Results
Visual inspection - Mechanical damage such as deformation, separation, crack, loosening of screw, etc.	No abnormal was found
Performance check – LED on check	Pass

RX-9 Sensor operate without damage even under severe shock conditions.

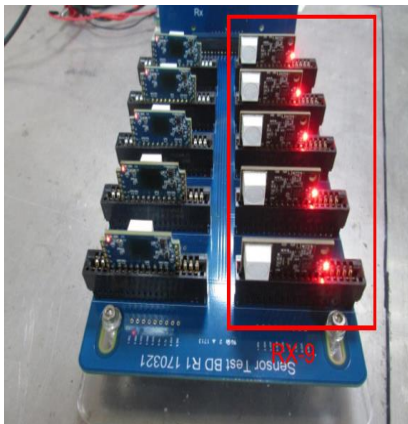
Test Condition & Equipment



- ▶ Test Equipments
: ESD SIMULATOR / NSG438 / SCHAFFNER
- ▶ Test Site
: Shield Room
- ▶ Environment Conditions
: Temperature : 21°C
: Humidity : 40% R.H.
: Atmospheric Pressure : 100.1kPa
- ▶ Test Point : Pin 1 to 9

PASS

Test Results

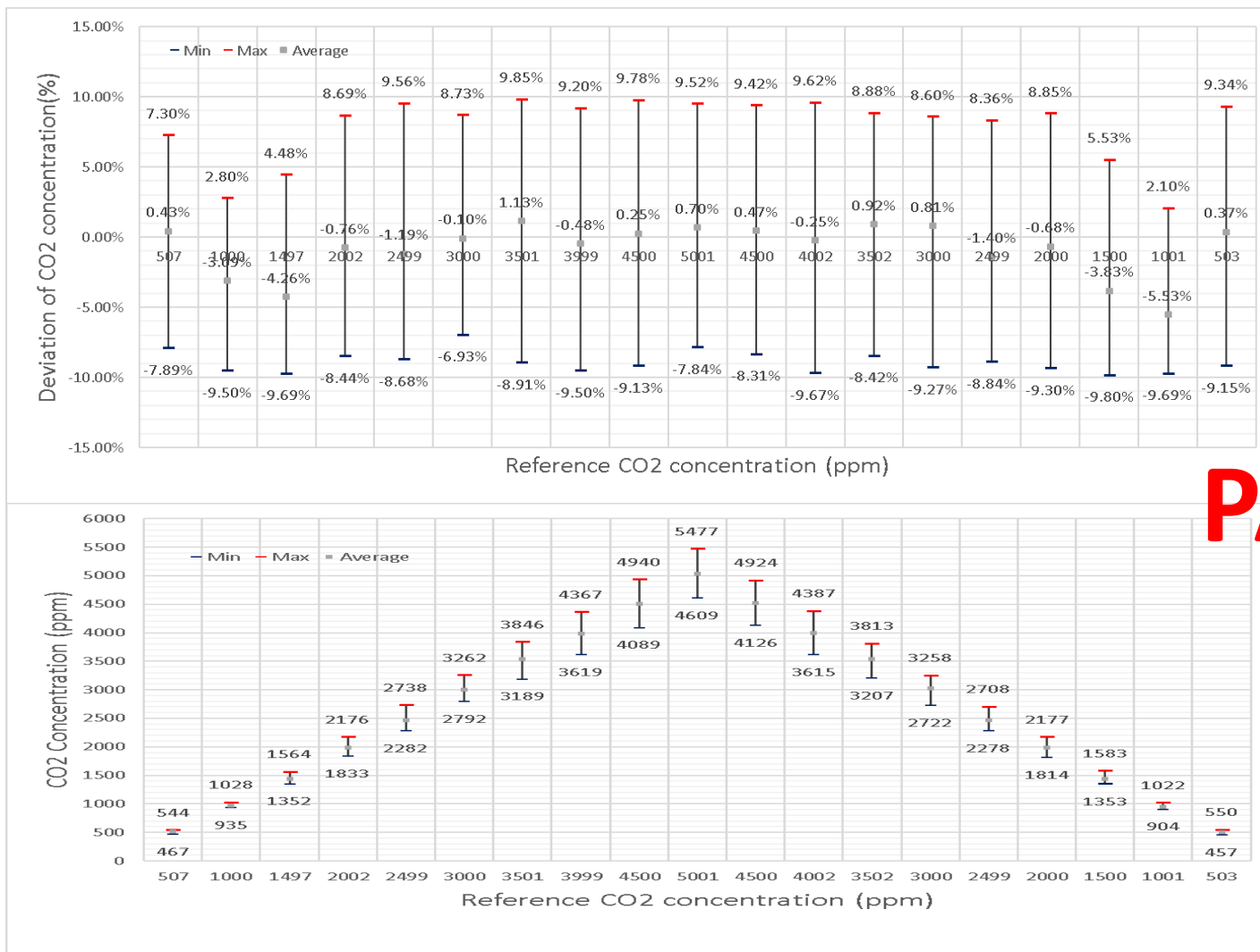


Direct Application					
Model	Discharge Method	Number of Discharge	Level (Kv)		Results
RX-9	Contact	≥10 times	+4	-4	Pass

※ Remark : LED was checked by inserting Test Jig after the test.

Accuracy Test Results (1)

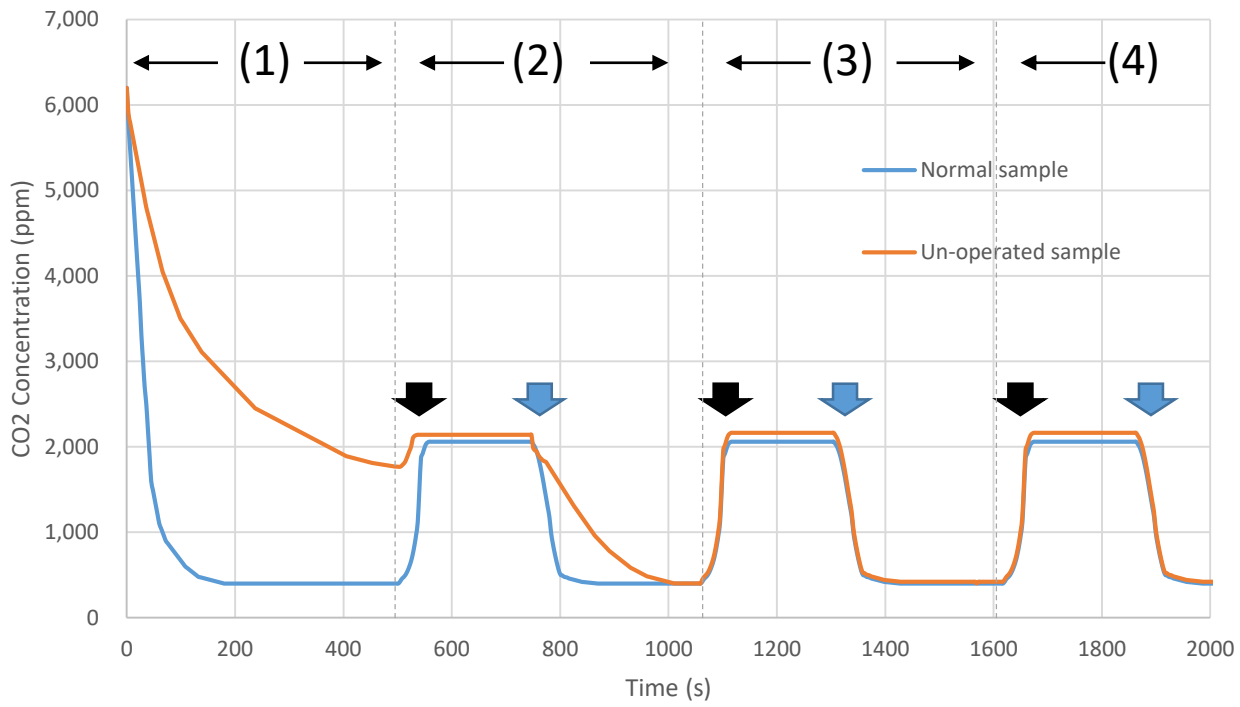
Error rate of RX-9 sensor compared to reference instrument when standard carbon dioxide concentration changes from 500ppm to 5,000ppm (No. of test samples : 35)



Accuracy Test Results (2)

Ref(ppm) No.	507	1000	1497	2002	2499	3000	3501	3999	4500	5001	4500	4002	3502	3000	2499	2000	1500	1001	503
#1	512	985	1523	1993	2429	2928	3480	3895	4406	4926	4433	3923	3488	2978	2435	2005	1540	968	506
#2	467	959	1368	1853	2394	2878	3415	3708	4324	4841	4319	3704	3391	2879	2368	1833	1353	987	516
#3	489	1006	1526	2141	2738	3135	3681	4148	4885	5477	4780	4140	3653	3140	2708	2117	1507	953	533
#4	470	949	1362	1865	2421	2863	3189	3872	4089	4609	4126	3910	3207	2722	2437	1887	1389	942	529
#5	511	947	1463	1893	2332	2829	3353	3732	4252	4774	4246	3727	3328	2812	2305	1872	1447	918	511
#6	514	948	1402	1895	2324	2886	3460	3875	4386	4914	4408	3898	3463	2949	2325	1902	1414	926	473
#7	478	994	1430	2009	2475	3078	3688	4121	4651	5154	4680	4151	3698	3181	2483	2023	1449	979	540
#8	511	997	1495	2142	2727	3230	3662	4151	4940	5448	4924	4136	3627	3111	2690	2111	1469	937	499
#9	499	935	1404	2085	2560	3141	3721	4151	4673	5178	4707	4186	3736	3216	2573	2104	1428	925	492
#10	511	943	1419	1919	2350	2886	3450	3847	4358	4883	4385	3875	3458	2981	2356	1931	1436	926	504
#11	532	968	1453	2113	2670	3201	3629	4315	4899	5413	4900	4317	3611	3092	2650	2099	1444	925	517
#12	531	963	1450	2133	2589	3144	3739	4148	4659	5181	4686	4176	3747	3237	2595	2145	1467	946	545
#13	529	987	1530	2026	2480	2994	3569	3989	4505	5018	4500	3985	3545	3033	2454	2006	1515	938	487
#14	501	940	1392	1889	2308	2889	3454	3867	4387	4904	4378	3859	3426	2913	2278	1865	1373	912	550
#15	533	965	1446	1947	2392	2935	3491	3916	4433	4958	4470	3954	3509	3024	2408	1969	1473	958	490
#16	519	947	1410	1921	2366	2920	3489	3872	4392	4911	4386	3867	3464	2948	2339	1900	1394	918	496
#17	523	955	1408	1900	2329	2874	3459	3866	4377	4899	4399	3889	3462	2948	2330	1907	1420	933	480
#18	544	984	1485	2152	2633	3202	3803	4229	4759	5256	4788	4259	3813	3258	2641	2166	1504	969	513
#19	500	1028	1372	1855	2282	2847	3419	3795	4314	4822	4298	3780	3384	2868	2345	1914	1407	968	518
#20	516	941	1448	1884	2298	2792	3329	3734	4256	4770	4290	3769	3344	2824	2311	1903	1472	931	535
#21	513	944	1412	1914	2351	2928	3495	3925	4436	4956	4463	3953	3503	3026	2357	1926	1429	927	517
#22	526	958	1443	2006	2480	3063	3674	4115	4632	5148	4633	4117	3656	3137	2460	1992	1434	915	507
#23	485	942	1359	1983	2455	3047	3628	4074	4585	5103	4612	4102	3636	3126	2461	1995	1511	1022	519
#24	487	1016	1358	2092	2556	3149	3762	4186	4702	5223	4697	4182	3738	3226	2530	2072	1377	967	494
#25	537	969	1460	2148	2736	3244	3691	4192	4756	5358	4747	4184	3663	3150	2706	2124	1441	916	482
#26	539	969	1435	2176	2665	3262	3612	4367	4884	5406	4921	4387	3730	3245	2681	2177	1462	962	485
#27	516	988	1519	2133	2610	3160	3778	4244	4764	5277	4758	4239	3753	3237	2583	2112	1503	938	522
#28	477	952	1385	1836	2370	2843	3383	3758	4269	4855	4291	3781	3386	2872	2371	1843	1397	930	494
#29	520	1023	1564	2138	2621	3201	3846	4277	4807	5304	4836	4266	3756	3239	2629	2152	1583	1008	514
#30	539	964	1446	1985	2418	2954	3516	3919	4438	4955	4422	3904	3481	2965	2381	1954	1420	904	500
#31	541	982	1444	1953	2379	2944	3557	3965	4487	4996	4521	4000	3572	3052	2392	1972	1468	972	507
#32	480	1014	1352	1833	2497	2804	3363	3758	4269	4791	4296	3786	3371	2894	2503	1845	1369	997	473
#33	508	948	1443	1961	2410	2930	3485	3907	4424	4936	4425	3909	3467	2948	2390	1947	1434	905	507
#34	476	967	1387	1931	2423	2900	3381	3761	4272	4868	4299	3789	3389	2879	2429	1943	1404	950	459
#35	488	940	1370	1834	2359	2815	3272	3619	4225	4741	4220	3615	3248	2736	2333	1814	1355	924	457
Min (ppm)	467	935	1352	1833	2282	2792	3189	3619	4089	4609	4126	3615	3207	2722	2278	1814	1353	904	457
Min (%)	-7.9%	-9.5%	-9.7%	-8.4%	-8.7%	-6.9%	-8.9%	-9.5%	-9.1%	-7.8%	-8.3%	-9.7%	-8.4%	-9.3%	-8.8%	-9.3%	-9.8%	-9.7%	-9.1%
Max (ppm)	544	1028	1564	2176	2738	3262	3846	4367	4940	5477	4924	4387	3813	3258	2708	2177	1583	1022	550
Max (%)	7.3%	2.8%	4.5%	8.7%	9.6%	8.7%	9.9%	9.2%	9.8%	9.5%	9.4%	9.6%	8.9%	8.6%	8.4%	8.9%	5.5%	2.1%	9.3%
Average (ppm)	509	969	1433	1987	2469	2997	3541	3980	4511	5036	4521	3992	3534	3024	2464	1986	1443	946	505
Average (%)	0.4%	-3.1%	-4.3%	-0.8%	-1.2%	-0.1%	1.1%	-0.5%	0.3%	0.7%	0.5%	-0.3%	0.9%	0.8%	-1.4%	-0.7%	-3.8%	-5.5%	0.4%
STD	22.38	26.25	55.52	112.08	136.37	147.88	161.72	198.50	228.41	228.75	222.73	197.25	159.38	154.98	131.84	108.57	53.58	29.45	22.68

FAQ 1) Long term Non-Operating Sample Properties



2,000 ppm
CO₂ 가스 주입

가스 배기

샘플 정보

- Normal Sample: 가동 샘플
- Un-operated Sample: 장기 비가동 방치 샘플

테스트 구간 정보

- (1)구간: Warming up
- (2)구간: 1차 가스 노출/배기 단계
- (3)구간: 2차 가스 노출/배기 단계
- (4)구간: 3차 가스 노출/배기 단계

- (1)구간: 장기 비가동 방치 샘플은 초기 안정화 시간이 가동 샘플에 비해 더 오래 걸림
 - (2)구간: 안정화 시간이 부족한 경우, 가스 주입시 변화량이 적음
 - (3)구간: 충분한 안정화시간이 주어지면, 장기 비가동 방치 샘플의 경우에도 가동 샘플 수준으로 복귀함
 - (4)구간: 재확인 결과 성능 회복 확인
- 장기 비가동 방치 샘플의 경우 센서의 안정화시간이 동작 샘플에 비해 길지만, 센서의 동작 메커니즘이 손상된 것은 아니며, 장시간 구동시 센서 본래의 신호를 회복함

PAPP Function

- **Sequence**
 - 전원 입력
 - Warm-up 시간 종료 직후, CO2 센서 출력값 확인
 - PAPP에서 설정한 값보다 높은 농도일 경우, 센서 Manual Calibration 실행
- **목적**
 - 센서 보관/이송 중에 발생한 누적 영향을 빠르게 제거하기 위함
- **기능**
 - 전원 인가 시 센서가 빠르게 정상값을 표시하도록 센서를 리셋함
- **실사용**
 - 고객 사용시 센서 값에 대해 의문이 생길 경우 전체 시스템의 전원을 재가동하면 센서 리셋을 시킬 수 있음
 - 고객 불만을 빠르게 해소할 수 있음
 - 개발 과정에서는 개발자들이 불만을 호소하는 경우가 있음

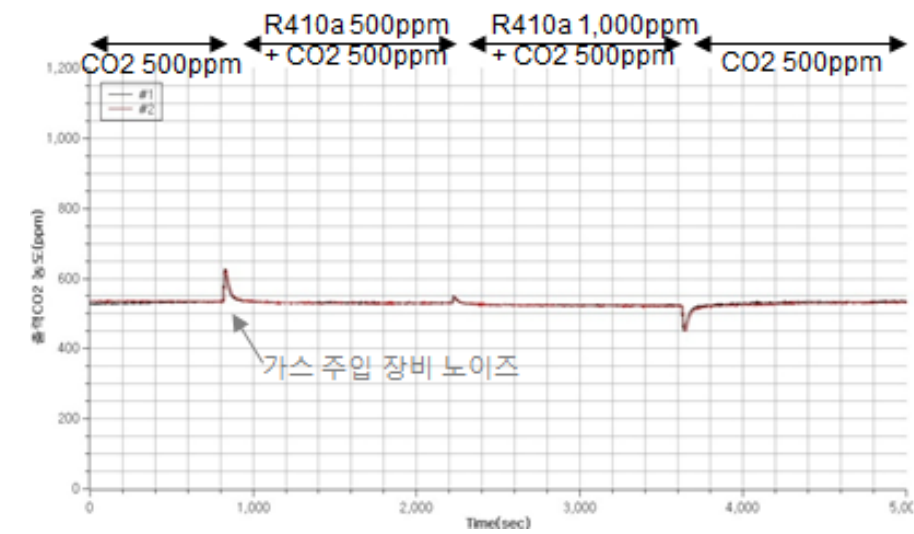
어플리케이션 별 PAPP 사용 현황

순번	Application	Setting value	Client
1	System Airconditioner	400	LG
2	Indoor Air Quality Monitor	6200	LG, COMMAX
3	Indoor Air Quality Monitor	400	KD
4	Air Cleaner	400	Prexco, HAATZ
5	Total Heat Exchanger	400	Air pass, HIMPEL, ...
6	Dash CAM	400	Chunho. Etc

FAQ 3) Interference of gases

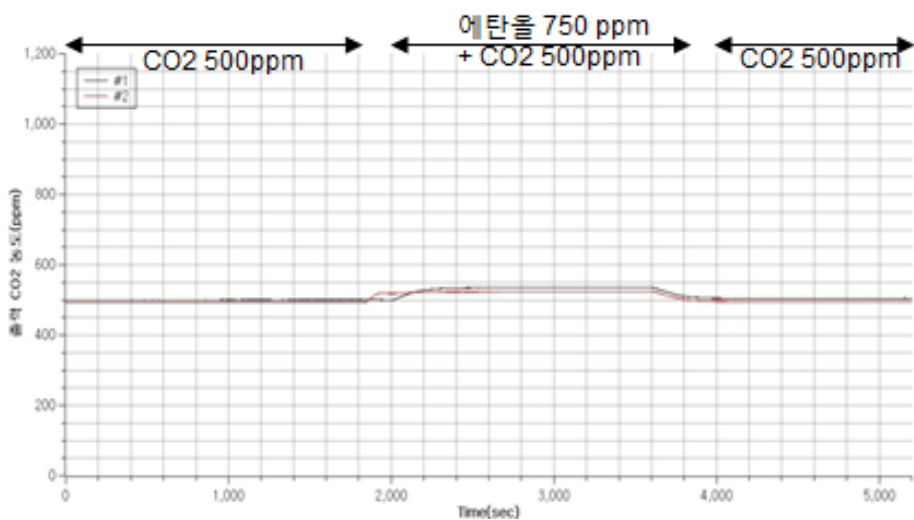
R410a

주입 농도 (ppm)	출력 CO ₂ (ppm)	
	#1	#2
CO ₂ 500ppm	535	530
CO ₂ 500ppm+R410a 500ppm	528	523
CO ₂ 500ppm+R410a 1,000ppm	524	520
CO ₂ 500ppm	537	533



에탄올 750 ppm

주입 농도 (ppm)	출력 CO ₂ (ppm)	
	#1	#2
CO ₂ 500ppm	499	491
CO ₂ 500ppm+에탄올 750ppm	535	524
CO ₂ 500ppm	504	494



THANK YOU!!