



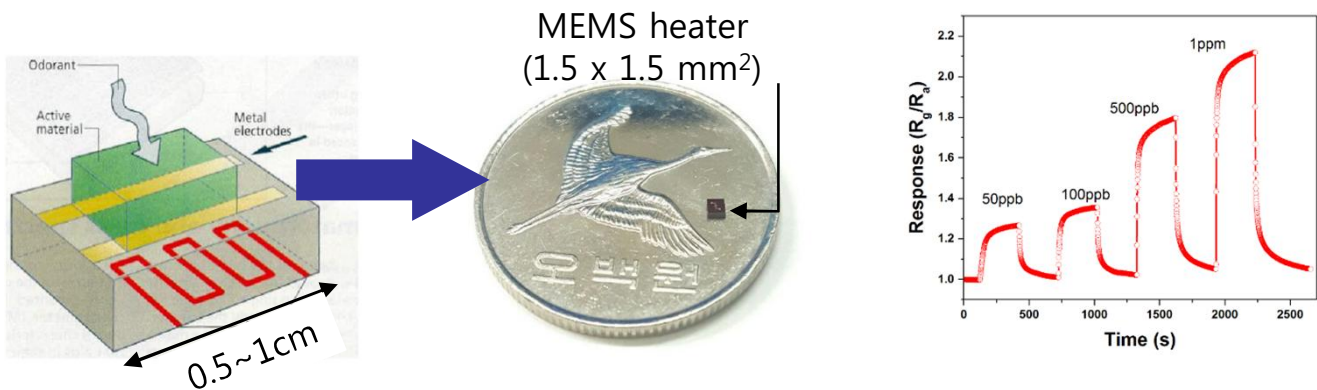
**High sensitivity / high  
selectivity MEMS  
formaldehyde gas sensor  
technology**

**Contact:** Heejin Choi  
Email: [hjchoi2@etri.re.kr](mailto:hjchoi2@etri.re.kr)  
Phone: +82. 42. 860. 4946

# TECHNOLOGY BRIEF

## Formaldehyde gas sensor on MEMS heater

### Technology Overview



#### <Characteristics of MEMS formaldehyde gas sensor>

- Monitor electrical resistance of elements depending on oxygen adsorption change through gas oxidation / reduction on detected substances (metal oxide)
  - Adsorption of oxidizing gas -> Decrease conductive electronics -> Increase conductivity of detected substance (for p-type material)
  - Adsorption of reducing gas -> Supply conductive electronics -> Decrease conductivity of detected substance (for p-type material)
- Heating (150-300 degrees) is required for effective response of gas oxidation / reduction on the surface of metal oxide.
- Conventional bulk heaters composed of metal line on alumina consume large amount of power. MEMS heater is developed for gas sensor having low power consumption.

### Keywords

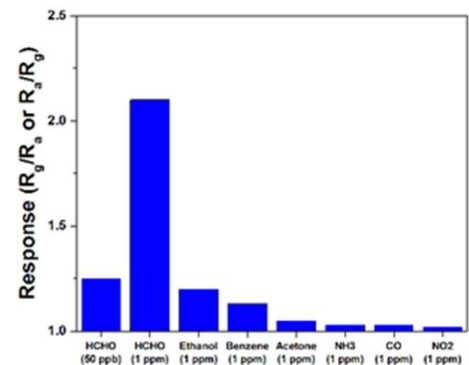
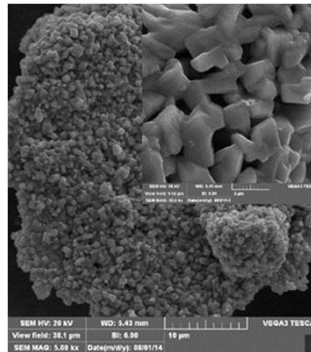
HCHO gas sensor, MEMS heater, high sensitivity, selectivity to HCHO

# TECHNOLOGY BRIEF

## MEMS formaldehyde gas sensor technology

### Technology Description

MEMS microheater  
(1.5 x 1.5 mm<sup>2</sup>)



<MEMS formaldehyde gas sensor>

< Formaldehyde detected substance  
SEM image and selective gas sensor >

#### Specs of MEMS micro-heater

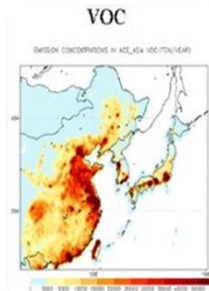
- Power consumption: 10~15mW at 300 degrees
- Size of micro-heater die: 1 x 1 mm<sup>2</sup>
- Heating area: < diameter 100 um

#### Specs of high sensitivity / high selectivity of HCHO detected materials

- High sensitivity: 25% at 50 ppb HCHO  
(HCHO concentration to maintain standard air quality, 100 ppm (USA), 80 ppb (WHO/Japan/Korea/Canada))
- High selectivity: response to HCHO 1 ppm is at least 4 times higher than that of others such as alcohol, benzene, acetone, ammonia, carbon monoxide, nitrogen dioxide, and etc. under the same concentration

### Application Fields

- Environmental sensor, gas sensor, air quality monitoring for outdoors and indoors, weather station, IAQ (indoor air quality) system for vehicles, and etc.



## ▣ Outstanding Features

### ▶ Competitive / substitution technology

- Figaro Inc. and AMS Inc. commercialized gas sensor using semiconductor based bulk heater. Power consumption of 200 ~ 800 mW to operate gas sensor.
- SGX sensortech Inc., Citytech Inc., and Senko Inc. commercialized electrical chemical gas sensor, but its only limited to 6 months ~ 3 years of use.
- Optical gas sensor is specialized to sense hundreds to thousands of ppm for specific gas such as CO<sub>2</sub>, CH<sub>4</sub>.

### ▶ Excellence compared to competitive / substitution technology

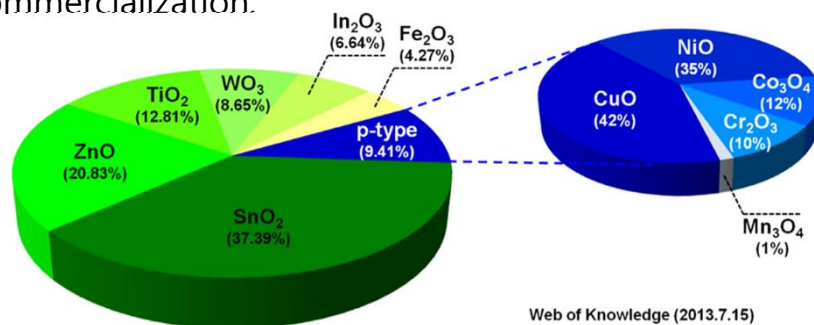
Competitive Technology	Excellence of new technology
Electrical chemical gas sensor	<ul style="list-style-type: none"><li>▪ Although electro chemical gas sensor has excellent selectivity, there are constraints of needing to use electrode from expensive metal.</li><li>▪ This new technology makes mass production of highly sensitive/selective HCHO sensor possible based on metal oxide materials and MEMS technology</li></ul>
Optical gas sensor	<ul style="list-style-type: none"><li>▪ Although optical gas sensor is very accurate, its big size and high price makes it hard to use.</li><li>▪ Miniaturized sensor having minimal size of 1 x 1 mm<sup>2</sup> through this technology, can be applicable to mobile device or IoT device.</li></ul>

## ▣ IPR Status

Korean patent 2 applicable

## Technology Trend

- Gas sensor based on semiconductors has been researched actively due to advantages such as variety of detected gas, easy manufacturing, and large market scale.
- Metal oxide sensing material is the most important factor of the sensor. N-type semiconductor ( $\text{SnO}_2$ ,  $\text{ZnO}$ ,  $\text{TiO}_2$ ,  $\text{WO}_3$ ,  $\text{In}_2\text{O}_3$ , and etc), of which electrons act as charge carriers, has a fast reaction rate. P-type semiconductor ( $\text{CuO}$ ,  $\text{NiO}$ ,  $\text{Co}_3\text{O}_4$ , and etc), of which holes act as charge carriers, is superior in operational stability because of large amount of absorbed oxygen on the surface.
- One-dimensional nano-material such as wire, rod, tube, and ribbon for sensing is being developed for high sensitivity, small size, and low power.
- Although nano gas sensor based on semiconductor is recognized as the most promising technology for the next generation gas sensors such as multi-gas sensor, e-nose, there are many conflicts such as target gas selectivity, environmental issues, operational stability that needs to be resolved for practical commercialization.



<Semiconductor Gas Sensor Material Research Status>

### Korea

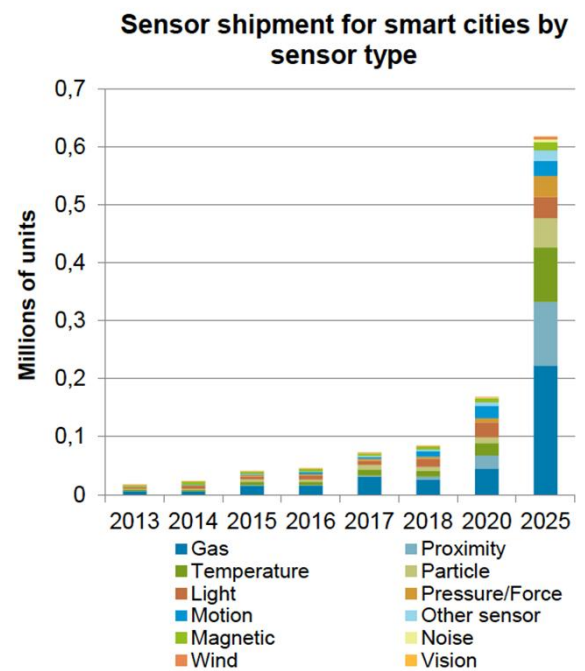
- Individual sensor (gas sensor, dust sensor, UV sensor) and multiple environmental sensor (temperature / humidity sensor) base on semiconductors to make MEMS and nano technology. This helps develop a low-priced, low-powered, high performance, high credible, small-sized, and digital sensor.
- Air quality sensor technology is used not only in monitoring the environment, but also in other industries such as automobile, consumer electronics, processing industries, and medical / health care.
- Global competitiveness is very weak, but some small firms have commercialized some few products such as chemical gas sensor.

### Global





- Figaro Engineering: Commercialized the traditional Taguchi type sensor and has the most shares in the semiconductor gas sensor market. Recently, low-powered product based on MEMS micro heater has been released.
- SGX Sensortech: Bought e2v社 to enter not only electro chemical gas sensor market, but also in semiconductor gas sensor market.
- Not only Figaro engineering and SGX Sensortech, which research semiconductor gas sensors, but also firms such as FIS, Honeywell, Siemens, Aeroqual have actively researched to produce products due to higher demands to monitor air quality of indoors / outdoors.

## Market Trend

- The whole gas sensor market is expected to be \$2.32 billion in 2018, and 20% is expected to be semiconductor gas sensor. (Research & Market, 2015)
- Compact / low-powered / low-priced MEMS gas sensor entered the market in 2015, and will expected to have \$500 million in 2017. (IHS, 2013)
- The demand for compact / low-powered / low-priced VOC (HCHO) gas sensor is increasing rapidly, but a secure source of supply has been difficult to find.
- World market for air purifier is expected to increase 16% annually from \$3.8 billion in 2013 to an expected \$9.2 billion in 2019. (KISTI, 2015)
- An increase demand for gas sensor to monitor air quality for IoT service in smart home and smart city. Gas sensor is the number one priority that needs to be developed than proximity sensor, temperature sensor, or dust sensor. (IHS, 2014)



## Market Leaders

Product name	Product photo	Core technology	Efficiency	Note
MLV-P2 (Ams AG, Austria)		<ul style="list-style-type: none"> <li>Semiconductor</li> <li>MEMS type</li> </ul>	<ul style="list-style-type: none"> <li>Various <b>VOC nonselective detection</b>: alcohol, aldehyde, ketone, organic acid, amine, aliphatic hydrocarbons etc.</li> <li>Power consumption: 34mW (@320degree celcius active) <ul style="list-style-type: none"> <li>Low reation time</li> <li>H2 / selective of humidity</li> <li>TO-39 header / 9x9mm<sup>2</sup> PCB</li> <li><b>No private ROIC</b></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Early stage of commercializati</li> <li>Deliver wigg</li> <li>home monitor</li> <li>system</li> </ul>
GS8100 (Figaro, Japan)		<ul style="list-style-type: none"> <li>Semiconductor</li> <li>MEMS type</li> </ul>	<ul style="list-style-type: none"> <li>Detect ethanol, H<sub>2</sub>, CO, isobutane</li> <li><b>Not selective of gas in low concentration (~1ppm)</b></li> <li>Power consumption: 15mW <ul style="list-style-type: none"> <li>3.2x2.5x1.0mm<sup>3</sup></li> <li>Ceramic package</li> <li><b>No private ROIC</b></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Early stage of commercializati</li> </ul>
CHO gas sensor (Synkera, US)		<ul style="list-style-type: none"> <li>Semiconductor</li> <li><b>Bulk sensor</b></li> <li>(다공성) nano detecting material</li> </ul>	<ul style="list-style-type: none"> <li>Lowest detected 250ppb</li> <li><b>Power consumption: 250mW</b></li> <li><b>Not selective of CO gas</b> <ul style="list-style-type: none"> <li>TO-39 package</li> <li><b>No private ROIC</b></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Research prototype development stage</li> </ul>
CHO gas sensor (ETRI, Korea)		<ul style="list-style-type: none"> <li>Semiconductor</li> <li>MEMS type</li> <li>(다공성) nano detecting material</li> <li>Digital interface</li> </ul>	<ul style="list-style-type: none"> <li><b>HCHO lowest detected 60ppb</b></li> <li><b>Power consumption: 15mW</b></li> <li><b>Highly selective for ethanol and CO gas</b></li> <li>Environment friendly (85 degree / 85%RH / 100h sensitivity change &lt;10%) <ul style="list-style-type: none"> <li><b>Private ROIC</b></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Research prototype development stage</li> <li>Commercializati and</li> </ul>



## ■ Scope of Technology Transfer

- Low-powered MEMS heater manufacturing technology
- Technology of Precursor production detecting formaldehyde
- Heat treatment method of metal oxide for formaldehyde sensing material
- Paste formulation for formaldehyde sensing material
- Highly sensitive / selective formaldehyde gas sensor characteristics analysis

## ■ Applications and Effects

### ▶ IoT environmental sensor

- Measure air quality in enclosed work space: Use low-powered gas sensor to wirelessly monitor harmful gases in water / electricity / gas underground facilities.
- Safety management system in subway: Measure air quality and dust level in subway stations and provide the information on electronic display.
- Air quality management for healthcare in schools: Monitor air quality of classrooms. Automatic ventilation when the air quality is at a certain level to provide a healthier and more comfortable learning environment.
- Eco-friendly air purifier to prevent sick building syndrome: Use highly selective air purifier to prevent formaldehydes caused by sick building syndrome from new buildings, apartments, or furniture.

