# Research and Development of Smart Integrated Sensing System

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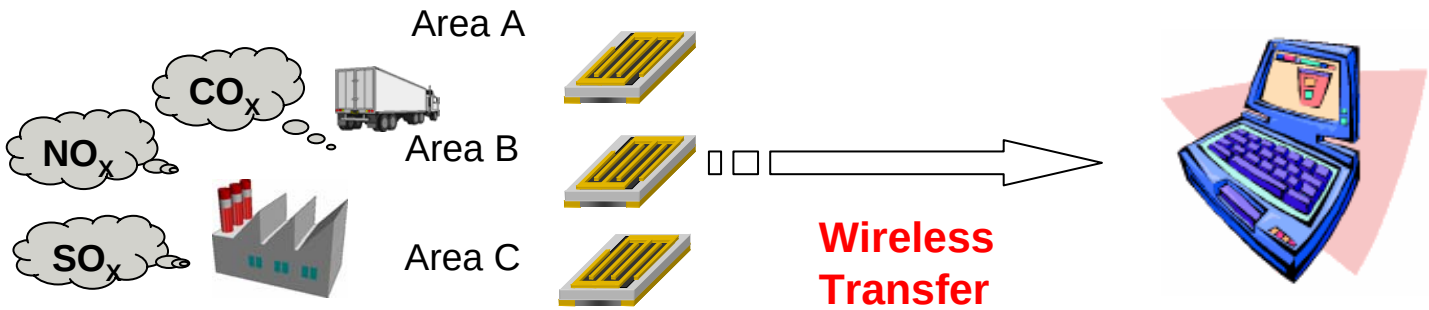
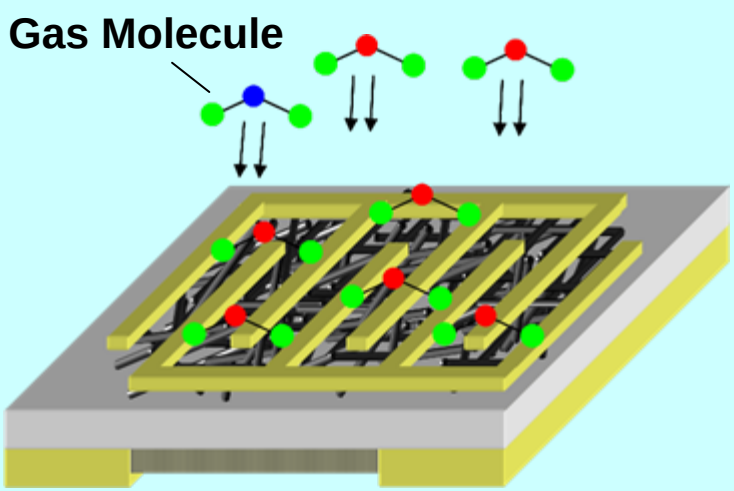
# Background

## Ubiquitous sensing system




**Ultrasensitive and low-power-consumption gas sensing device**




Gas Sensing Device

**Requirements for ubiquitous sensing:**

- High sensitivity
- Low-power consumption
- Molecular recognition
- Wireless communication

# Joint research systems (IDER unit)

## Synthesis of gas-sensing materials

**Leader: Honda**

Winadda, Fujii, Murata, Yoshihara, Ishida,
Inoue, Tanaka (Katayama Lab.)

## Characterization of gas-sensing materials

**Sub-leader: Abe**

Sugimoto (Osaka Univ. FRC)
Sawada (Morita Lab.)
Nagamura, Go (Unisoku Co., Ltd.)

## Fabrication of gas-sensing devices

**Sub-leader: Aoki**

Hyeon, Miyano, Hotta (Sugino Lab.)

## Design and simulation of gas-sensing devices and circuits

**Sub-leader: Matsuoka, Morifuji**

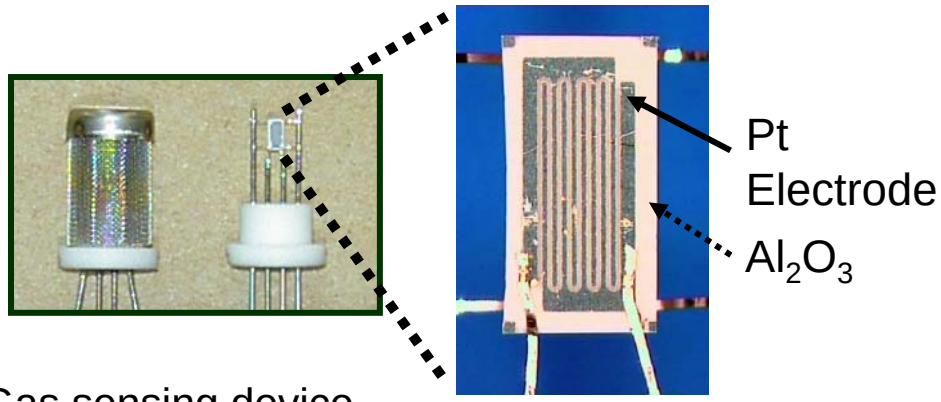
Wang, Kihara, Kim, Choji, Rin (Taniguchi Lab.)

**Adviser: Prof. Taniguchi, Prof. Katayama**

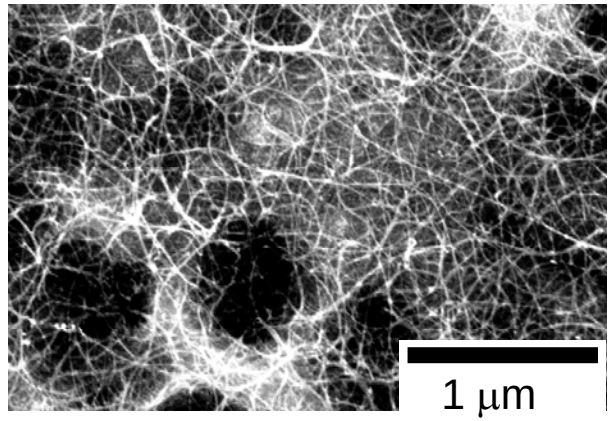
**Improvement of performance and functionality of gas-sensing devices**
**→ Application to environment**

# Results

## *Single-walled carbon nanotube thin-film sensor*




Gas sensing device




Single-walled carbon nanotube (CNT) network

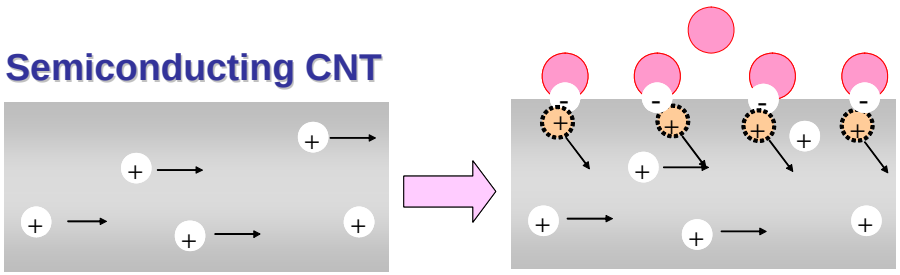
### Charge transfer due to gas adsorption

Electrons transfer from single-walled CNTs to oxidizing gas molecules

Oxidizing gas molecule
Electron
Hole

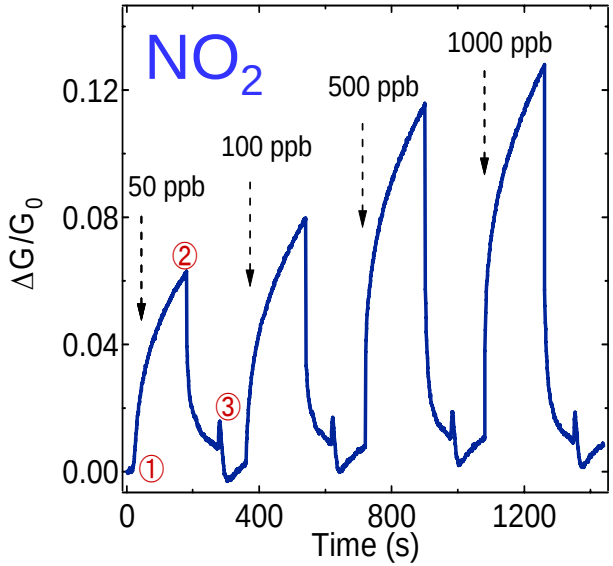
Conductance of the CNTs changes
(Hole density of the CNTs increases)

**Semiconducting CNT**



Before adsorption

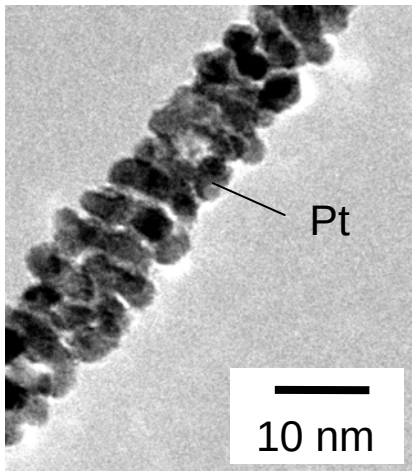
After adsorption



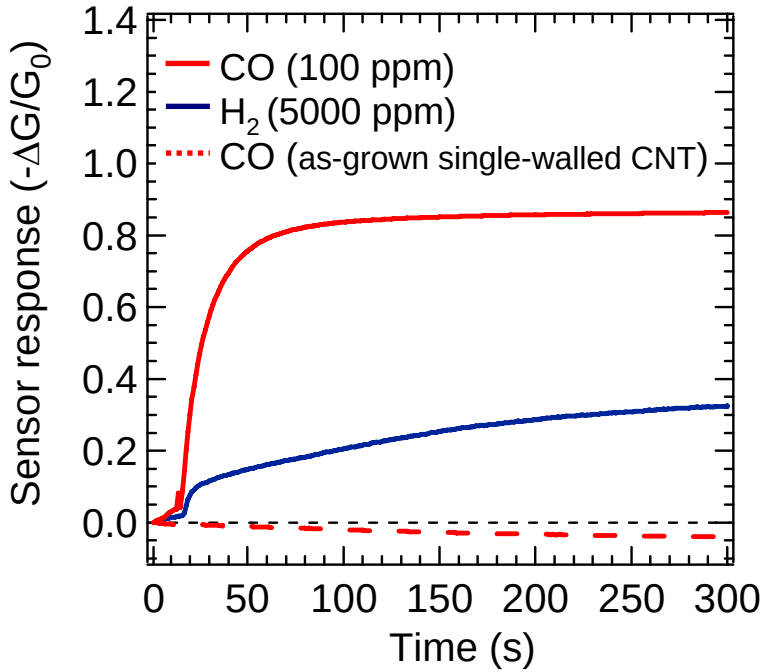

- Sensor response ($\Delta G/G_0$): $\Delta G = G_{gas} - G_0$,
  $G_{gas}$ = sensor conductance after gas exposure,
  $G_0$ = sensor conductance before gas exposure
- **① & ③: heater off, ②: heater on**

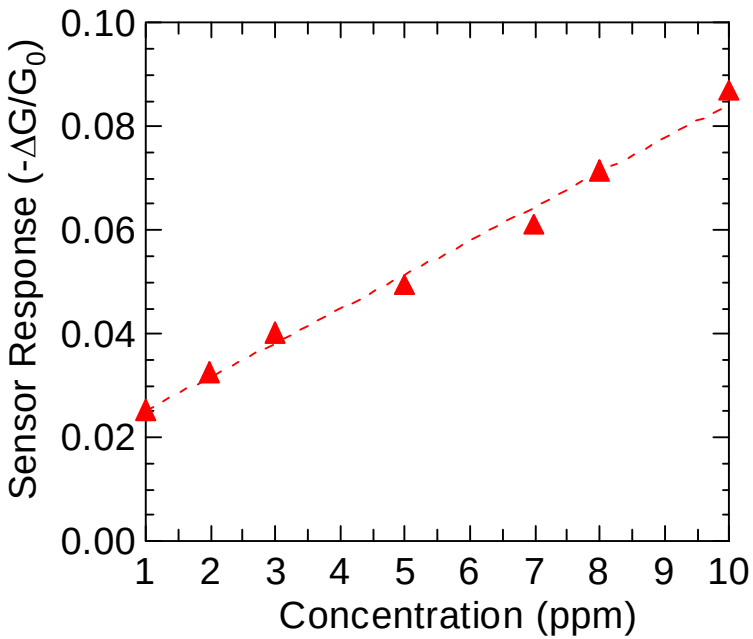
*Jpn. J. Appl. Phys.* **44**, L482 (2005).

# *Highly sensitive and selective detection of CO using Pt-decorated single-walled CNT*




**Pt-decorated single-walled CNT (Pt thickness: 5 nm)**



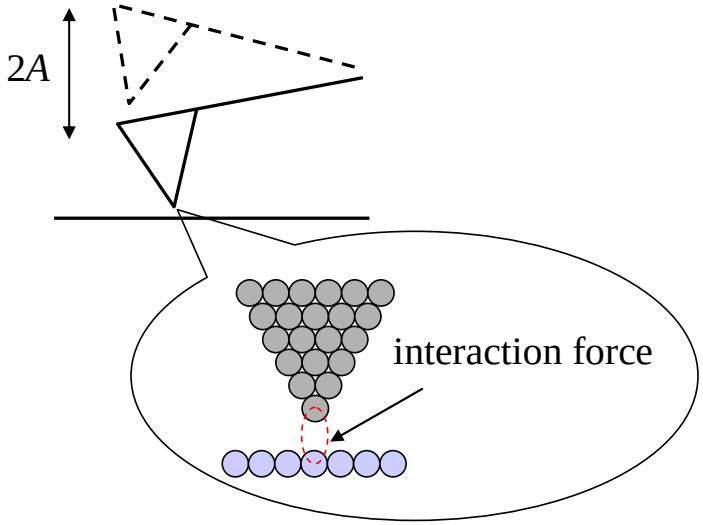

- CO detection down to 1 ppm
- gas selectivity against $H_2$
- quantitative detection of CO in a low-concentration range

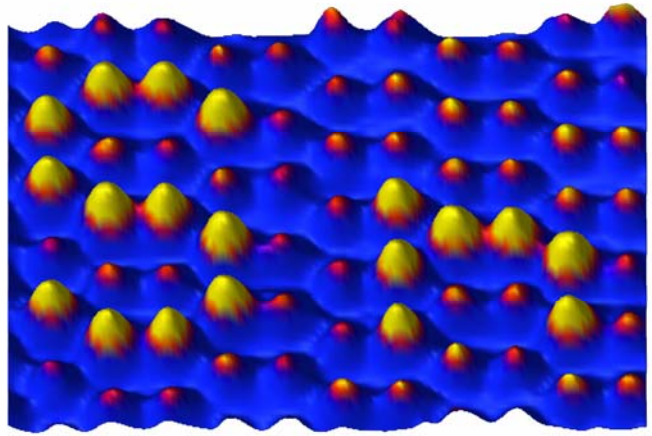
*Applied Physics Express* **1**, 014004 (2008).

# Research Plans (Ⅱ)

## Characterization of sensing materials

## Tool: Dynamic Force Microscopy (DFM)

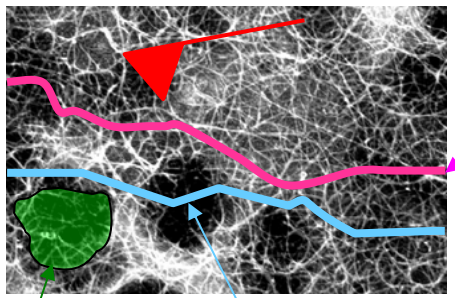


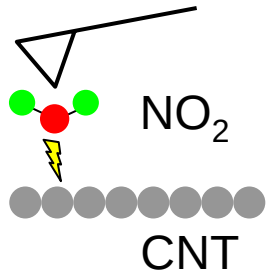
atom manipulation and imaging
at room temperature
(*Nature Materials* **4**, 156 (2005))

In this IDER, we will perform

1.nano-electric properties



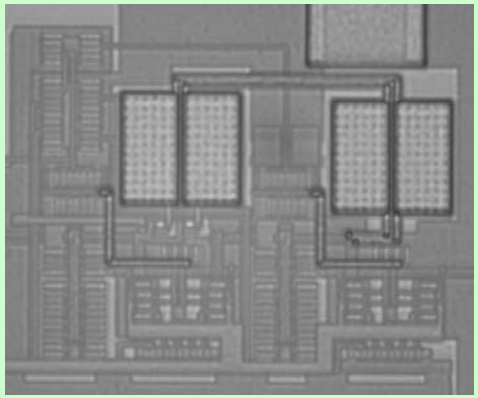

2. molecular manipulation and estimation of potential barrier



# Research Plans (Ⅲ)

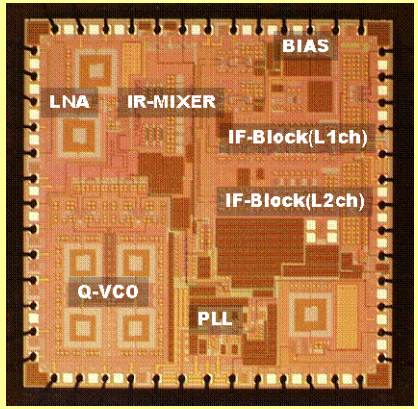
## IC Design for Smart Integrated Sensing System

### High-Precision Low-Power Analog Circuits for Sensing System

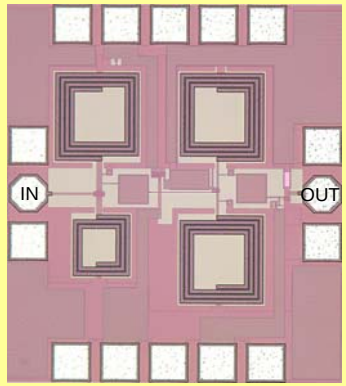


**1.5V Δ-Σ A/D Converter**
**(0.25 μm CMOS)**
(*IEICE Trans. Electron* **J90-C**, 662 (2007).)

### RF CMOS Circuits for Wireless Data Acquisition and Control




**GPS Receiver RF Front-end**
**(0.25 μm CMOS)**
(*IEICE Trans. Electron* **E88-C**, 1275 (2005).)




**5GHz Low Noise Amplifier**
**(150 nm FD-SOI CMOS)**
(*IEICE Trans. Fundamentals A* **E90-A**, 317 (2007).)

### Approach for CNT Sensing System

- **IC Design through Circuit Simulation**
- **Circuit & System Implementation**
- **CNT Characterization with IC Chip**