

# Digitalization and Innovation in the Food Supply Chain in the APEC Region PPFS Webinar 2021, Japan

## The Usage of Digital Technology at the Farm Level: Implementation of Smart Sensors in Orchard and Fish Farms for Yield Improvement

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# INSTITUTE OF MICROENGINEERING AND NANOELECTRONICS (IMEN)



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# IMEN'S RESEARCH THEMES



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- MEMS/NEMS and Nanoelectronics
- Organic, Hybrid, Flexible and Printed Electronics
- Nanophotonics and Quantum Electronics
- Microelectronics Semiconductor Packaging
- Micro and Nanoelectronics System

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# Implementation in Orchard



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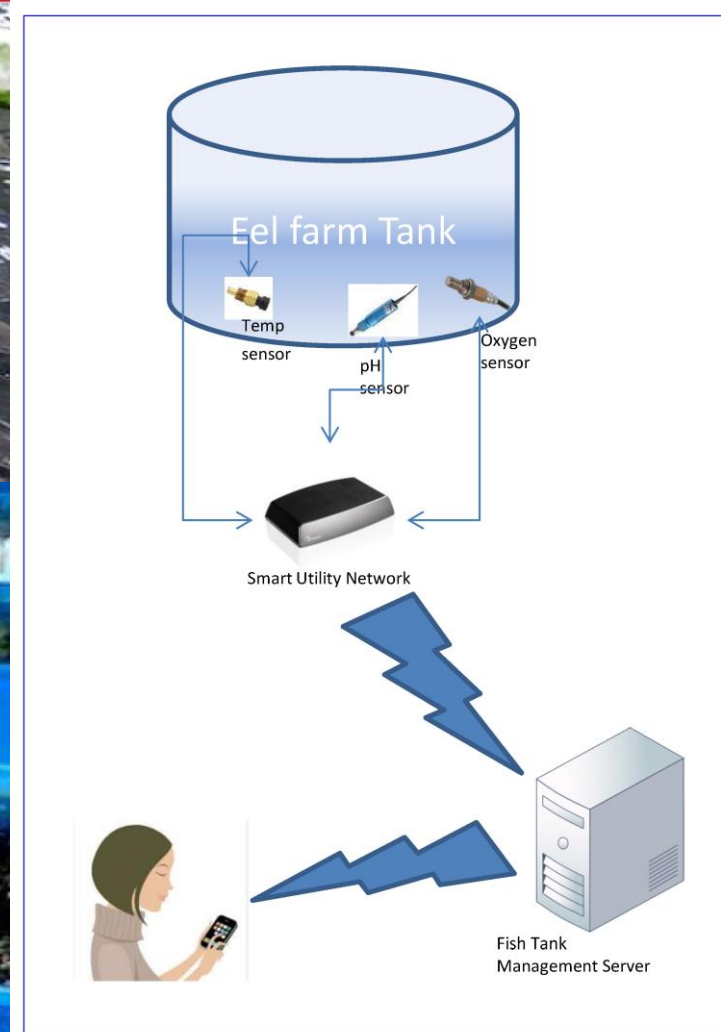




# Implementation in Fish Farm



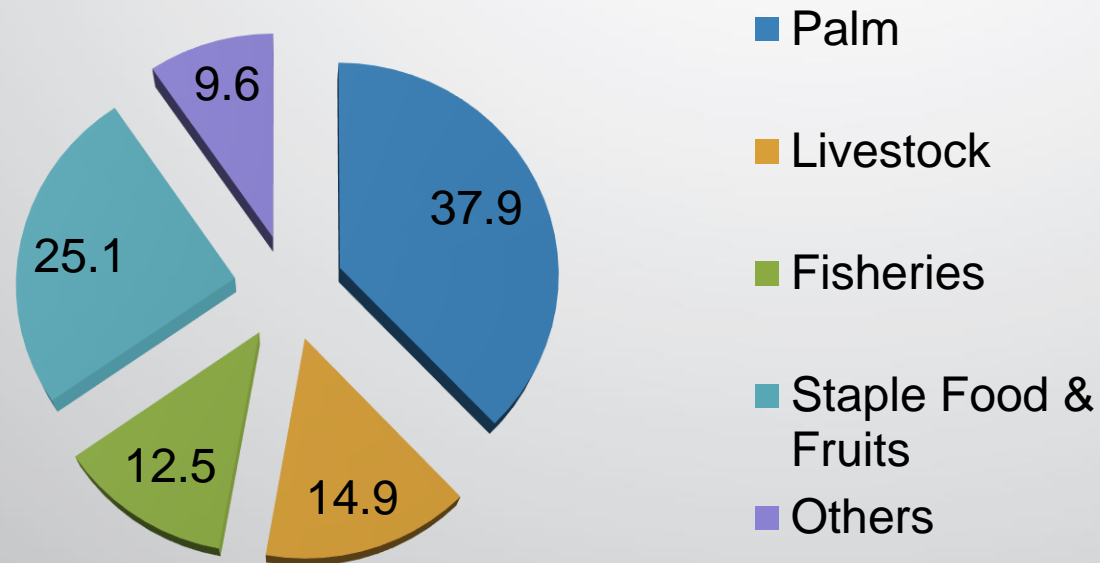
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# Agriculture Industry Breakdown and Contribution



## Percentage contribution of each sector



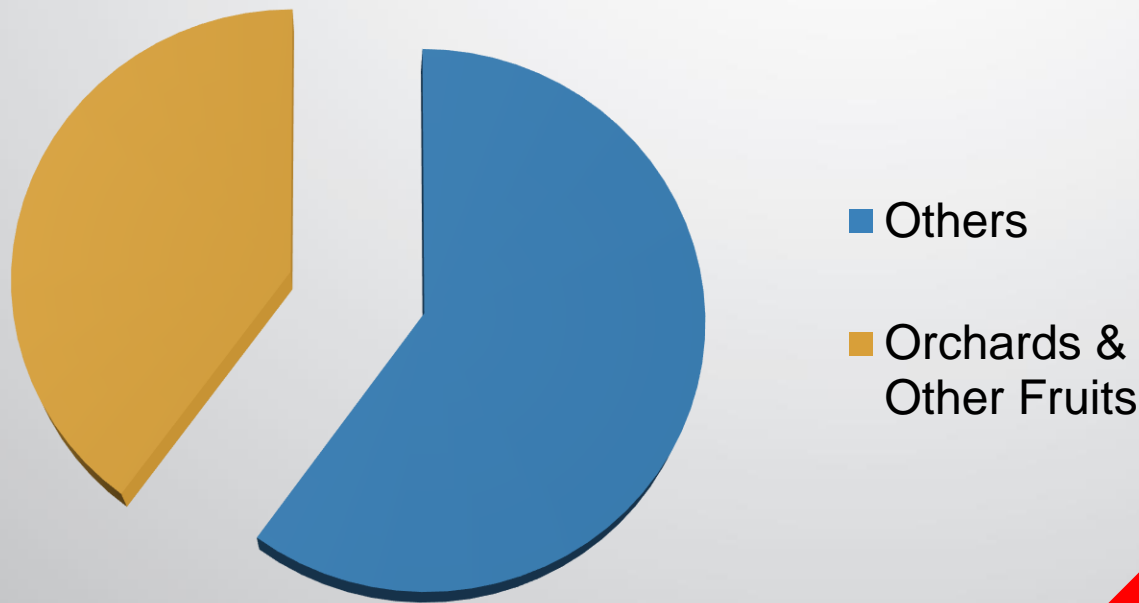
- **7.3% of Malaysian GDP**
- **MYR 105 billion (USD 25.5 billion)**

[1] Siaran Akhbar Indikator Pertanian Terpilih (*Press Statement of Selected Agriculture Indicators*), Malaysia, Jabatan Perangkaan Malaysia (*Statistics Department of Malaysia*) 2019.

# Staple Food & Fruits Industry Breakdown and Contribution



## Percentage contribution of sectors



**Orchard & other fruits :**

- **MYR 10.4 billion (USD 2.54 billion)**

**Smart Farming**



**Orchard Farmers Income**

[2] Fruit Crops Statistics 2019, Department of Agriculture Malaysia, 2019.

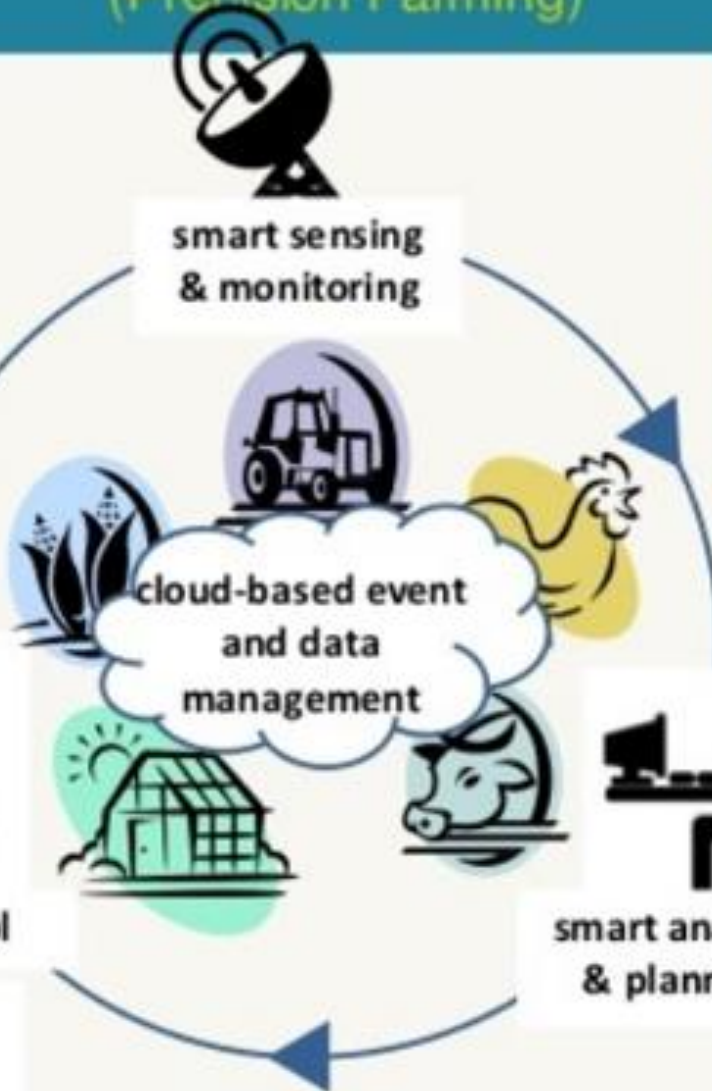


# IoT in Smart Farming

(Precision Farming)



smart control



smart sensing  
& monitoring

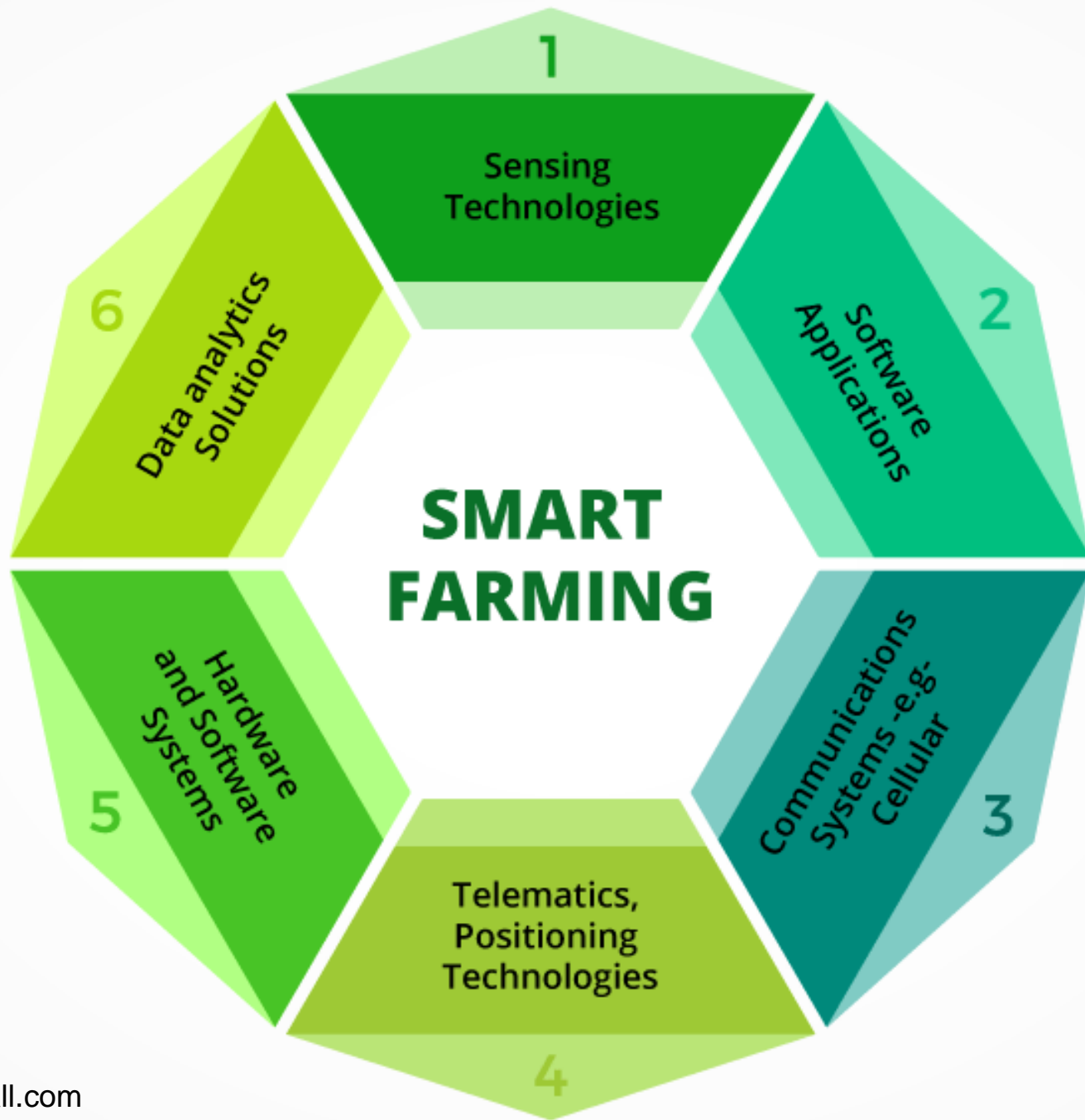
cloud-based event  
and data  
management

smart analysis  
& planning



Source: arcweb.com





# Partnership with Vector Kuala Lumpur



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# SENSORS IMPLEMENTATION

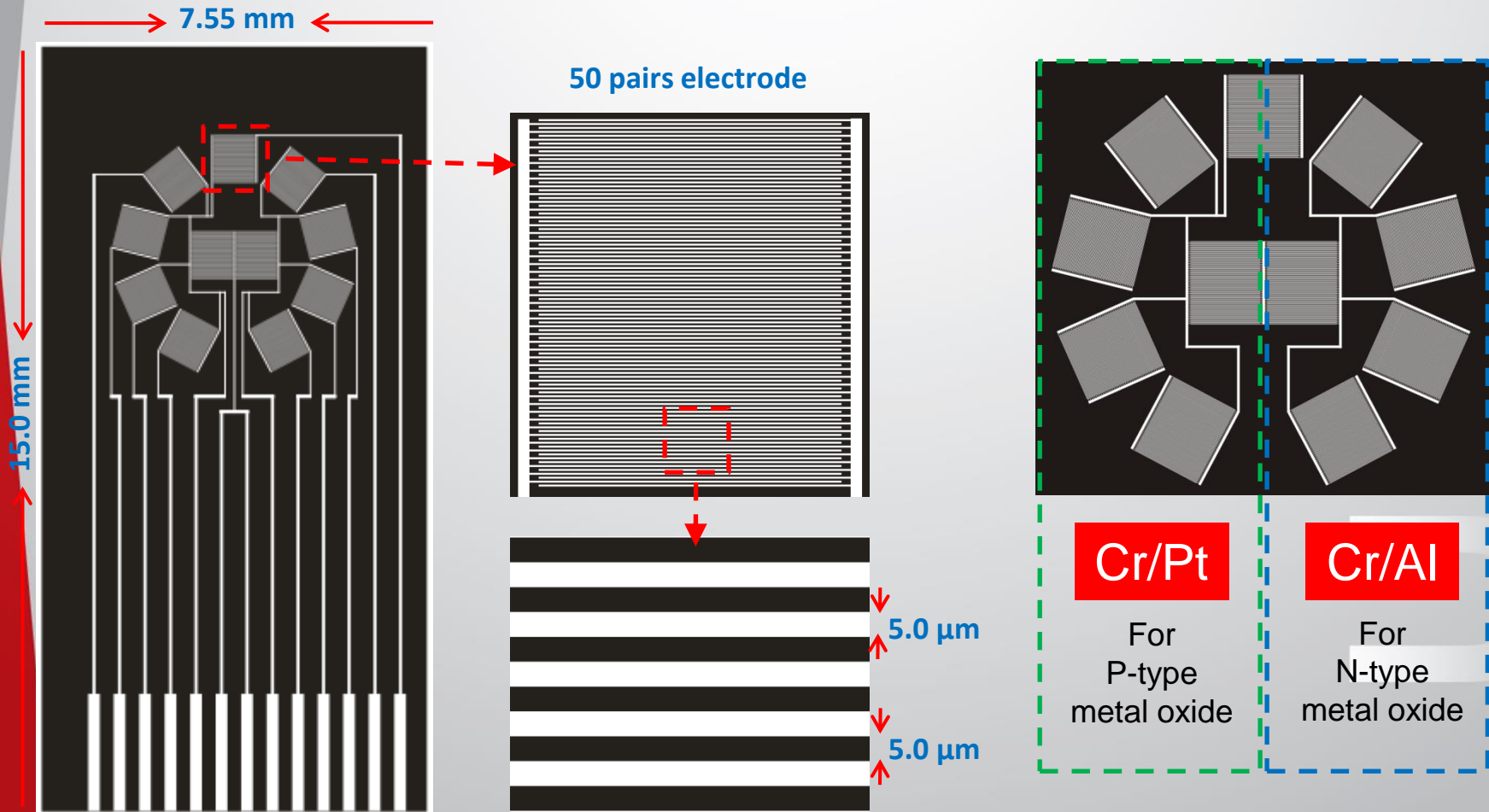


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# Electrical Biosensor

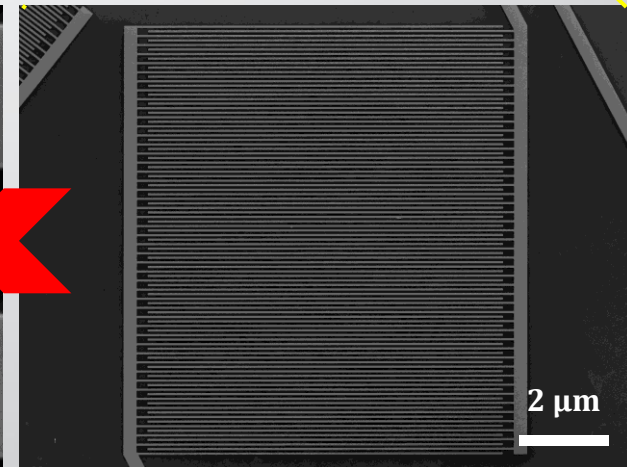
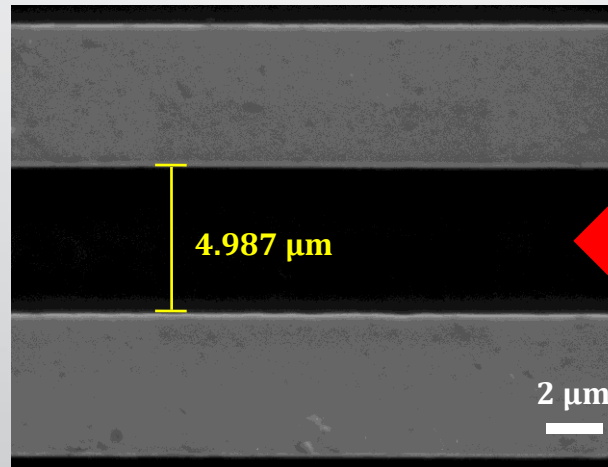
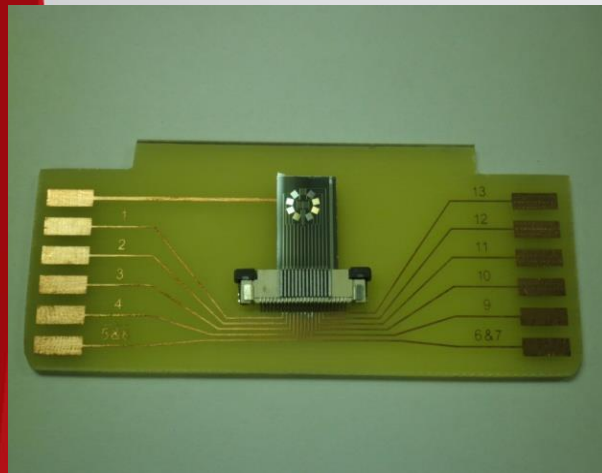
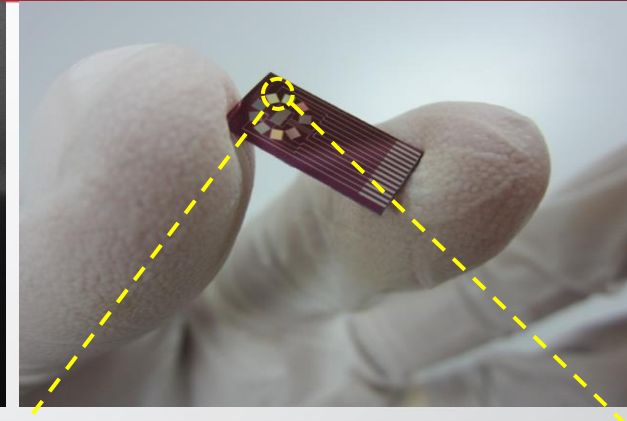
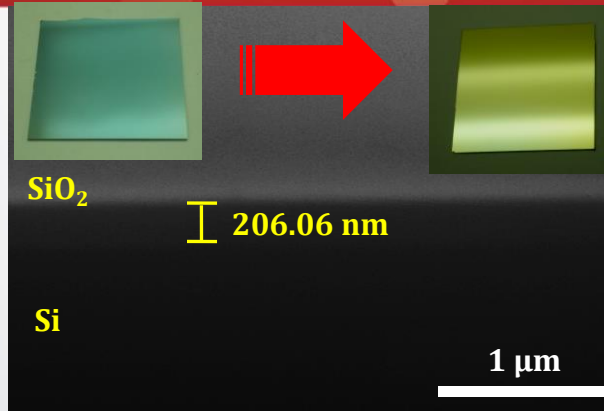
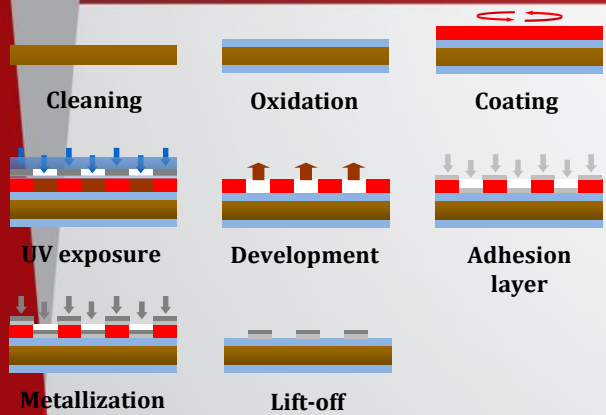


- To facilitate the alignment of metal oxide nanowires and the fabrication of an array sensor.



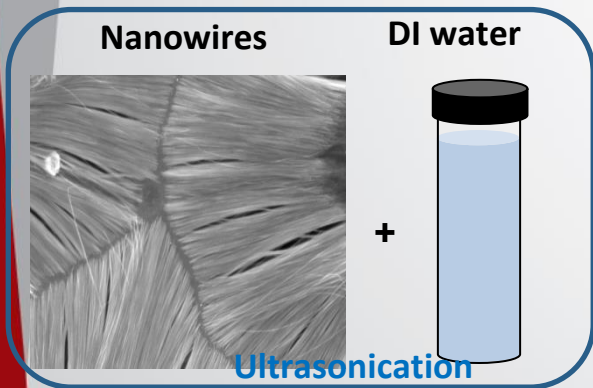


# Fabrication of IDE Chip

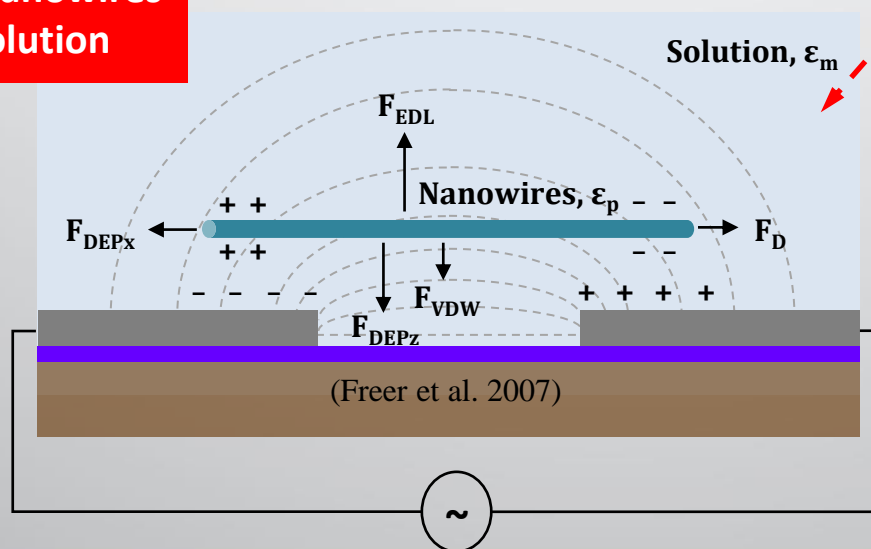
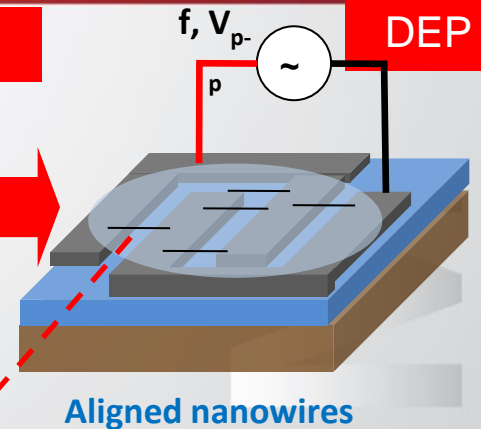
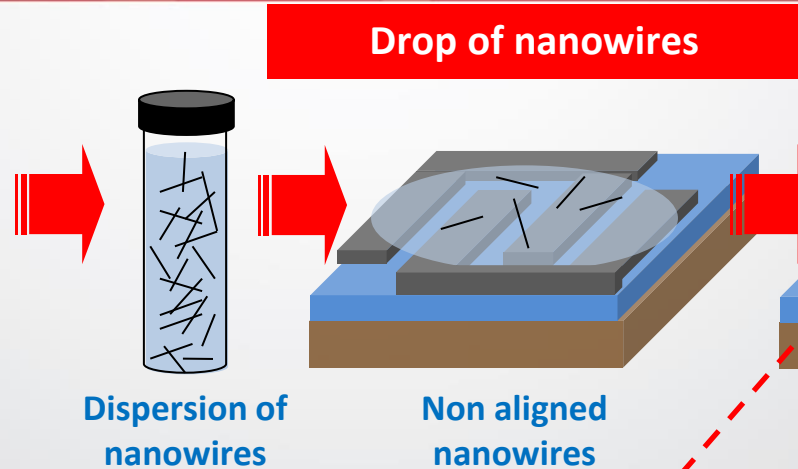


✓ IDE spacing:  $\sim 5 \mu\text{m}$  / Connection circuit on PCB through chip slot.

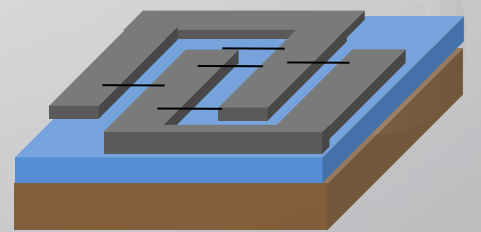
# Nanoarray Sensor



**Preparation of nanowires dispersion' solution**

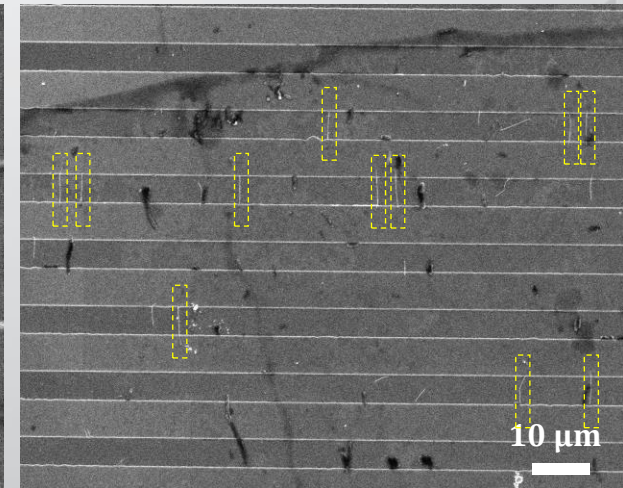
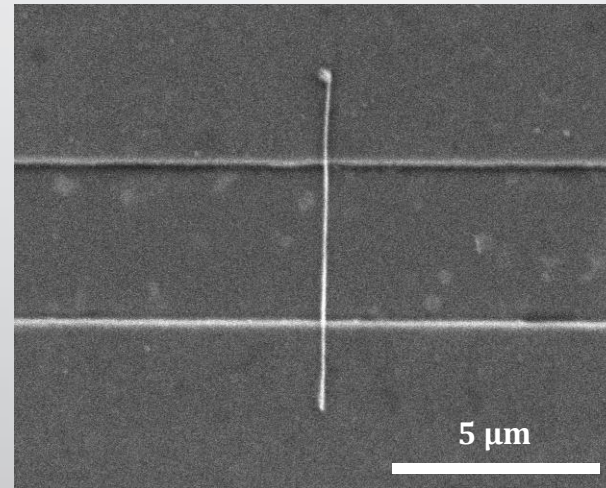
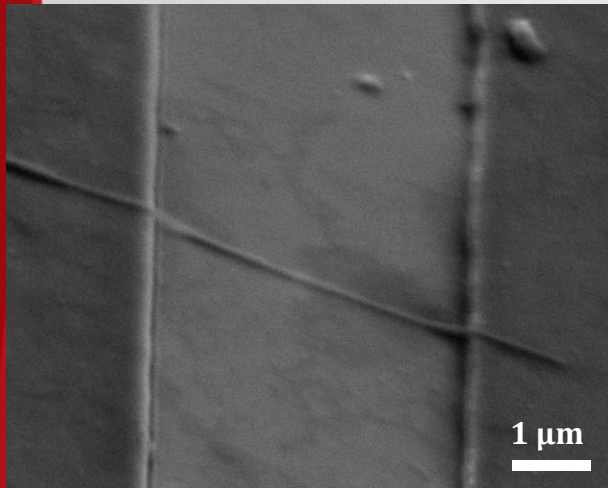
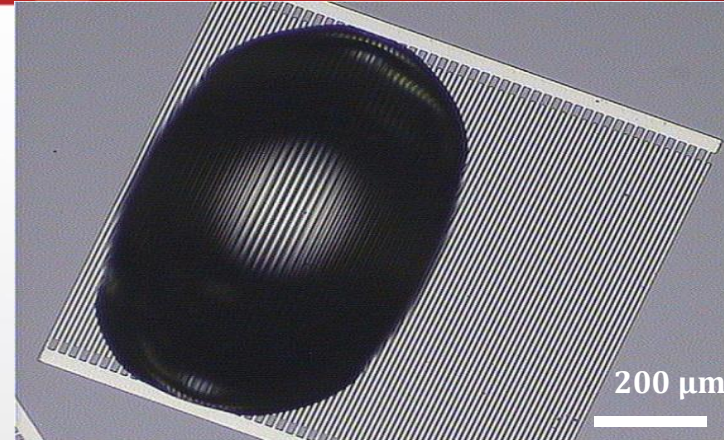
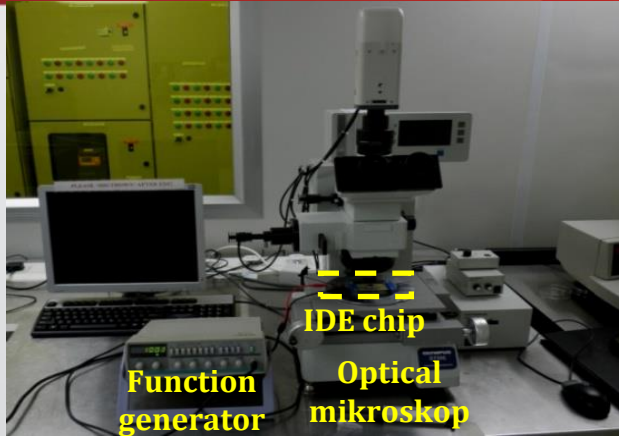


400°C, 20 min, N<sub>2</sub>-1500ml/min  
**Annealing**



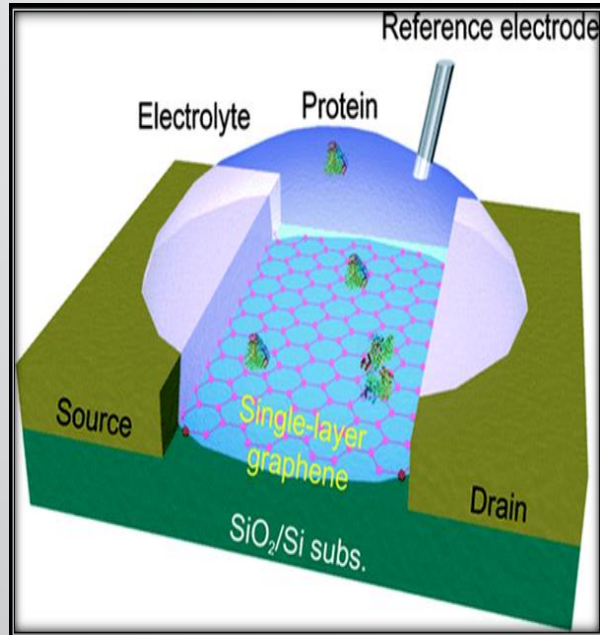


# Alignment of Nanowires



Dielectrophoresis parameter for alignment (AC: 10 V, 2 MHz).

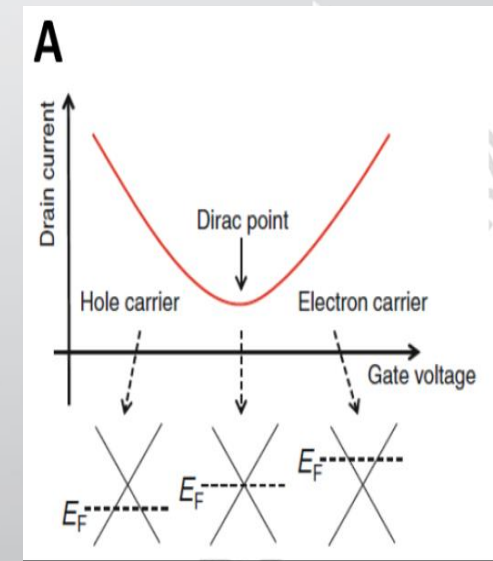
# GFET Sensor : Principle of Nanoparticle Detection



- ✓ Changes in the **conductance** of graphene sheet, indicates binding of protein on graphene surface.
- ✓ Changes in conductance can be measured by changes in drain current.
- ✓ These changes indicated in dirac point of ambipolar curve.

## Conductance based graphene biosensing

Ref: Tran, T. T., & Mulchandani, A. (2016). Carbon nanotubes and graphene nano field-effect transistor-based biosensors. *TrAC Trends in Analytical Chemistry*, 79, 222-232.

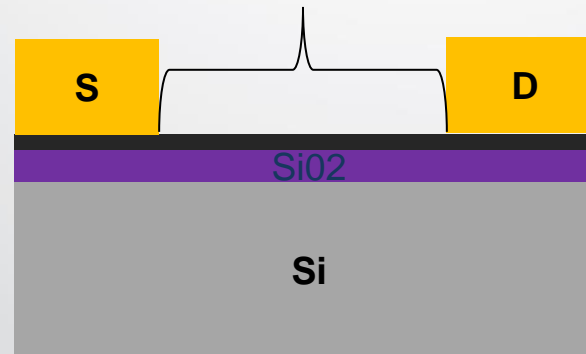




# Device-GFET (Graphene based Field Effect Transistor)



Graphene as conducting channel

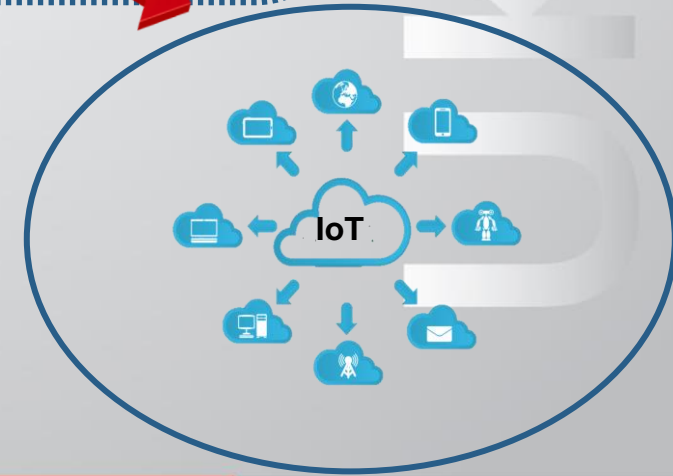
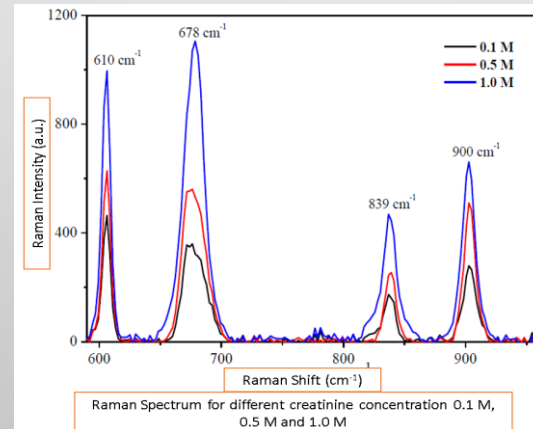
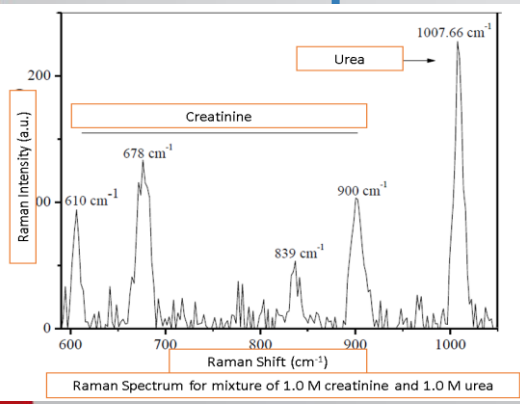
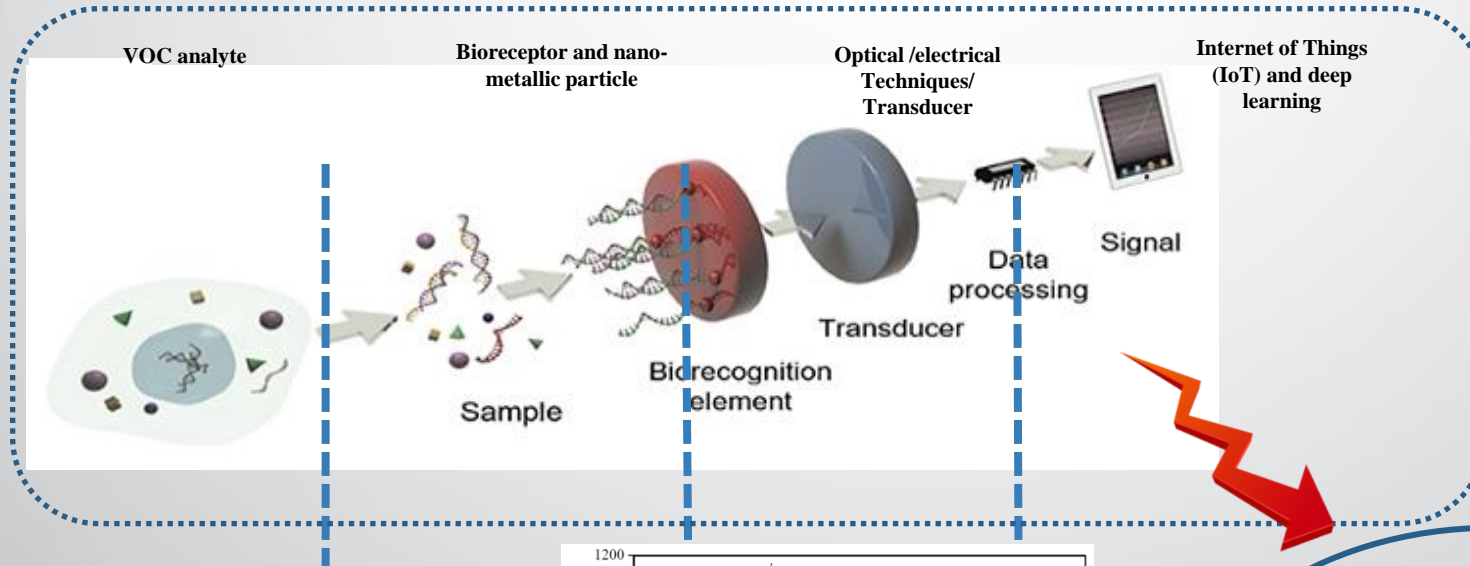


- Graphene
- Gold Electrode (acts as source and drain terminal)
- Silicon dioxide
- Silicon

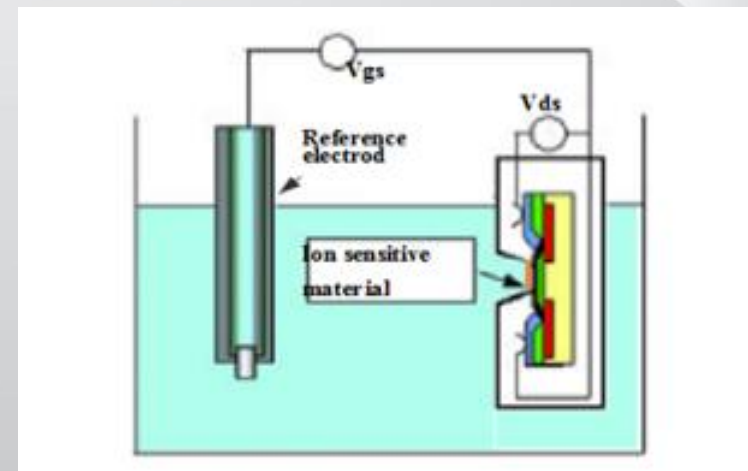
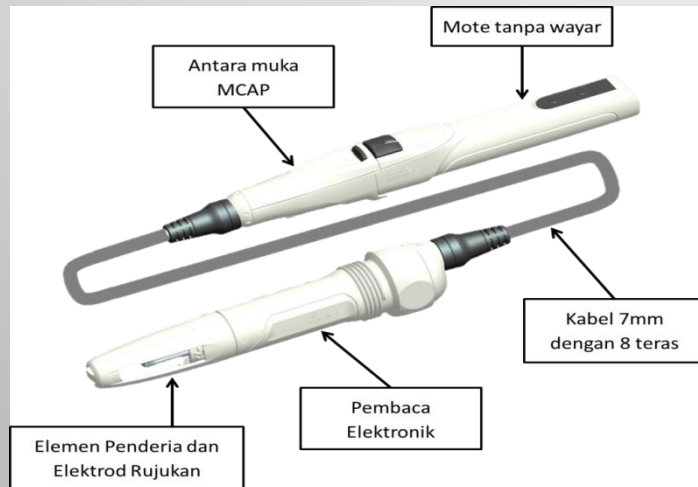
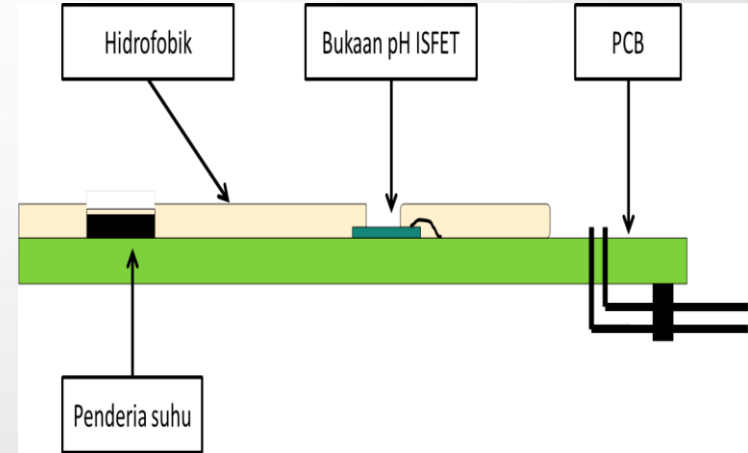
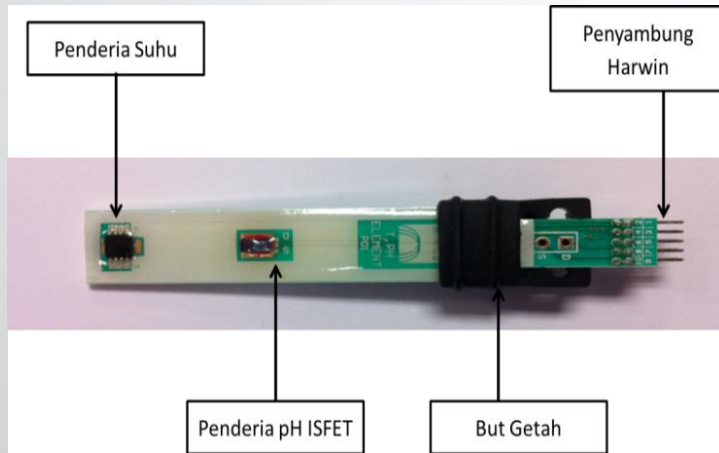




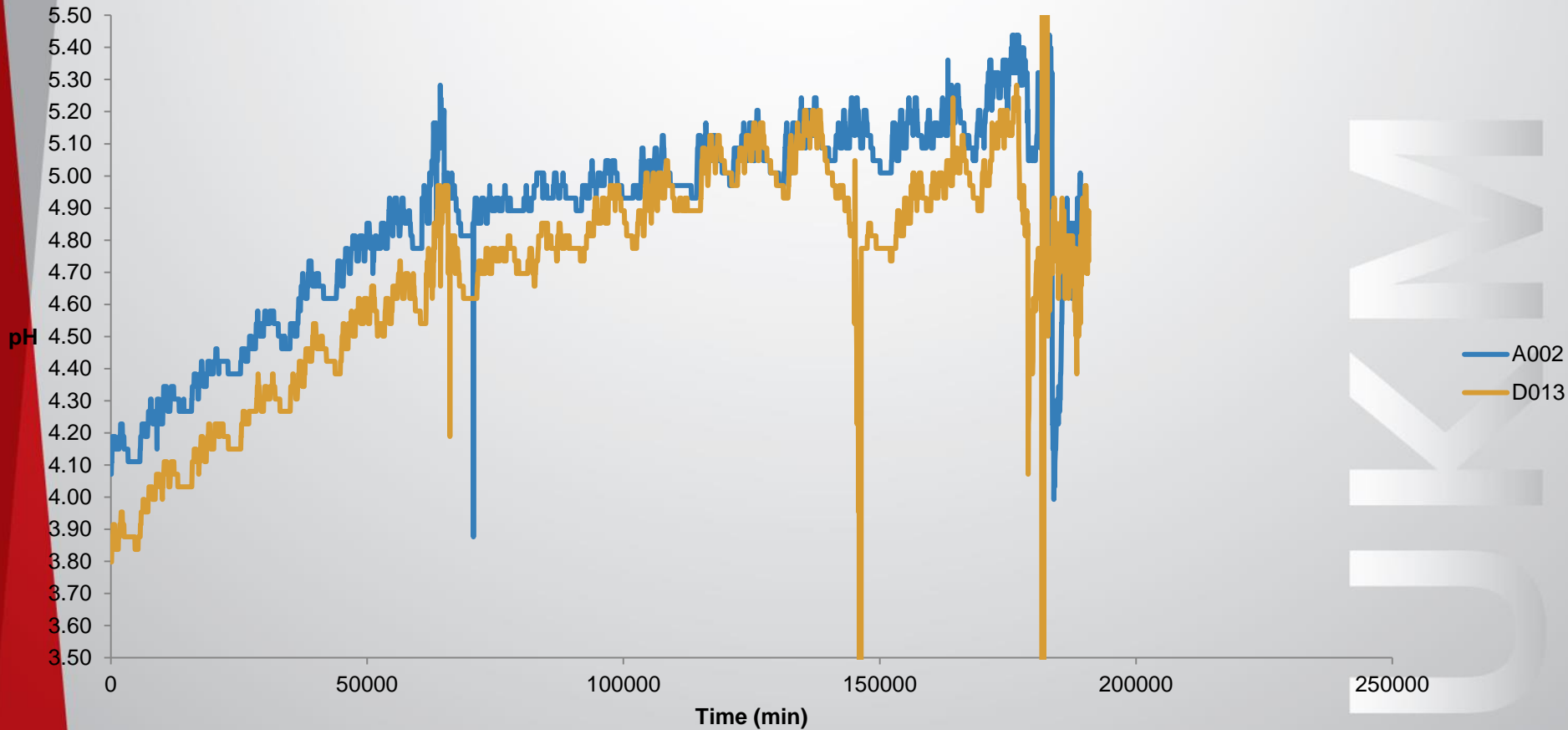
# VOC Sensor : Detection Mechanism



# Environment Sensor



# Field Drift Test

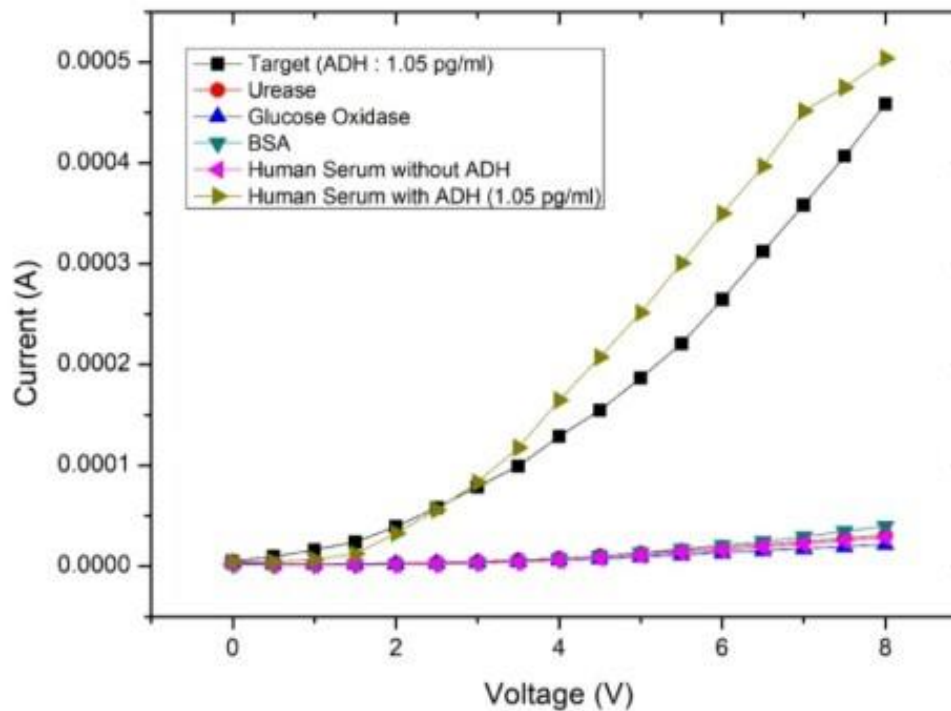


Drift test for 140 days in acidic environment (pH 4)

- 2 packaged units tested for more than 4 months



# Device sensitivity



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**THANK YOU**



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