Poster Session II: IoT Including Nanosensors

High-sensitivity and Low-power Flexible Schottky Hydrogen Sensor based on Silicon Nanomembrane

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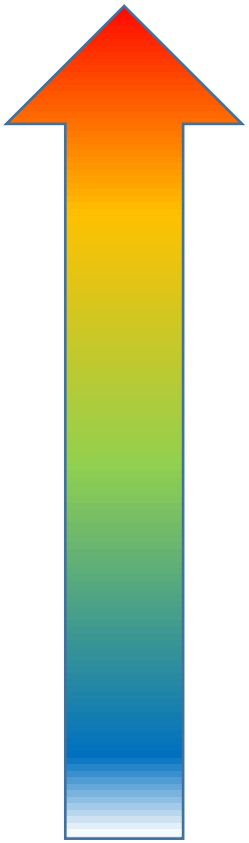
01 Hydrogen Sensor

- Hydrogen (H_2) is useful as a future clean energy resource and an ideal replacement for fossil fuel
- Various applications such as hydrogen vehicle, petroleum refining, glass purification, semiconductor manufacturing etc.
- H_2 is flammable at concentrations over 4% by volume, therefore high sensitivity H_2 sensor with fast response time is necessary
- Silicon nanomembrane based diode type H_2 sensor was demonstrated exhibiting high sensitivity and low power consumption

Source:http://www.hydrogen.energy.gov/systems_integration.html
US Department of energy

02 Semiconductors for flexible/wearable H_2 sensors

High Mobility



Graphene

Carbon Nanotubes

GaAs, GaN

***Si**

Poly-Si

a-Si

Polymers

Low Mobility

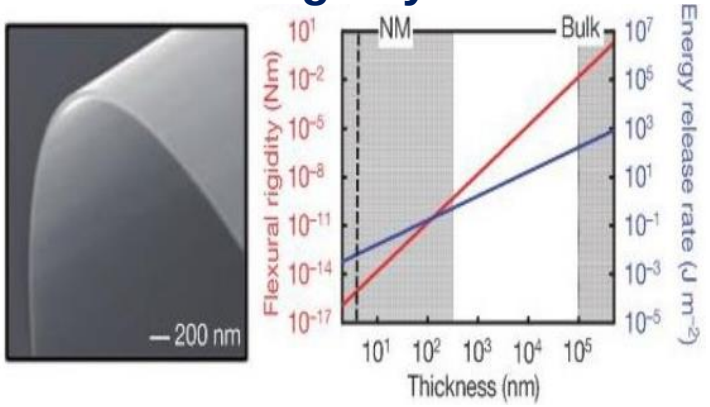
Advantages of Si

- Well established processing technique

-> more freedom in sensor design

+

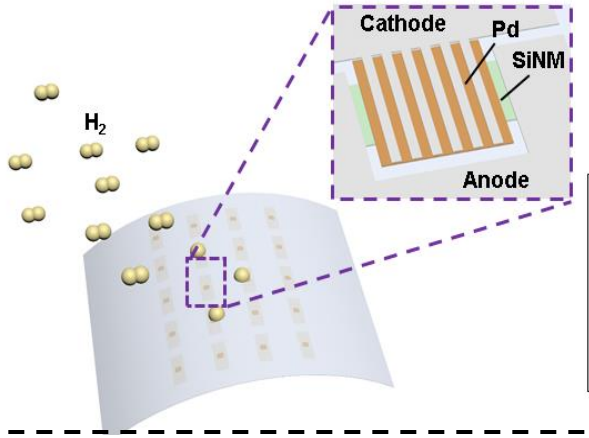
Low flexible rigidity of thin Si

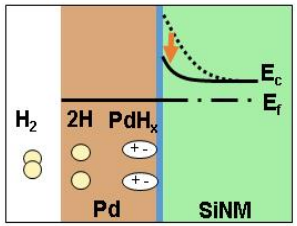


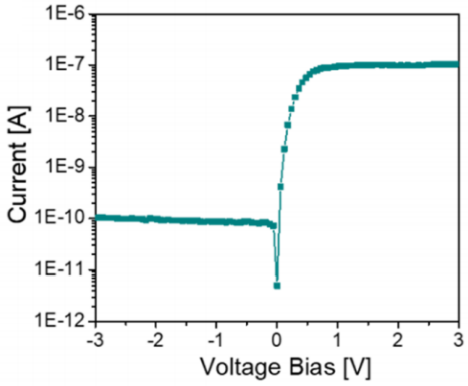
Good material candidate for high performance flexible/wearable H_2sensors

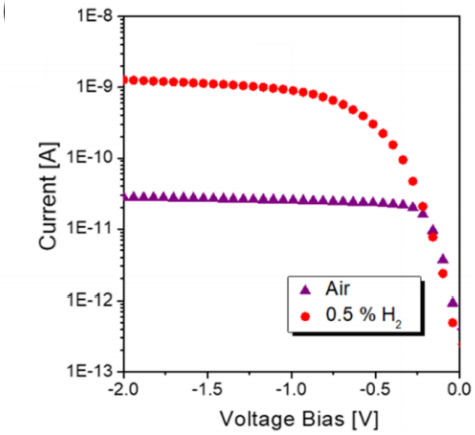
02 Operation Principle

- The operation principle of the sensor is based on Schottky barrier lowering effect upon exposure to H_2
- H_2 gas molecules are diffused into Pd layer forming Palladium Hydride (PdH_x) at Pd/Si interfaces
- Device simulations show that effective current quenching has been occurred in 50 nm thickness SiNM H_2 lowering standby power consumption of the sensor



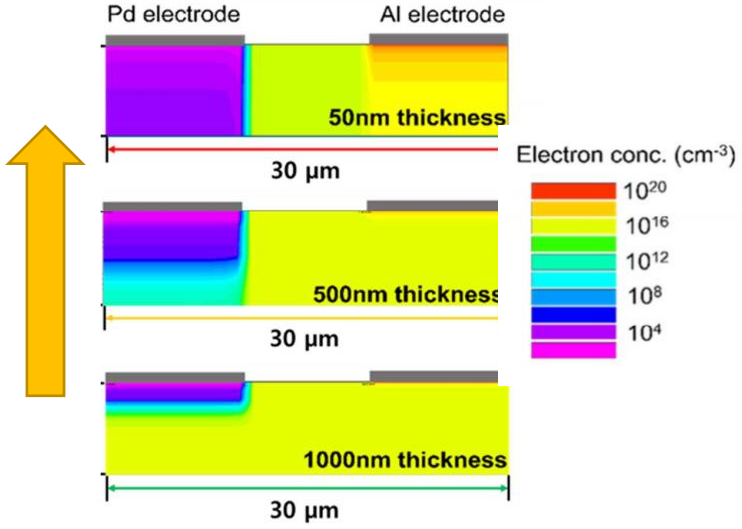




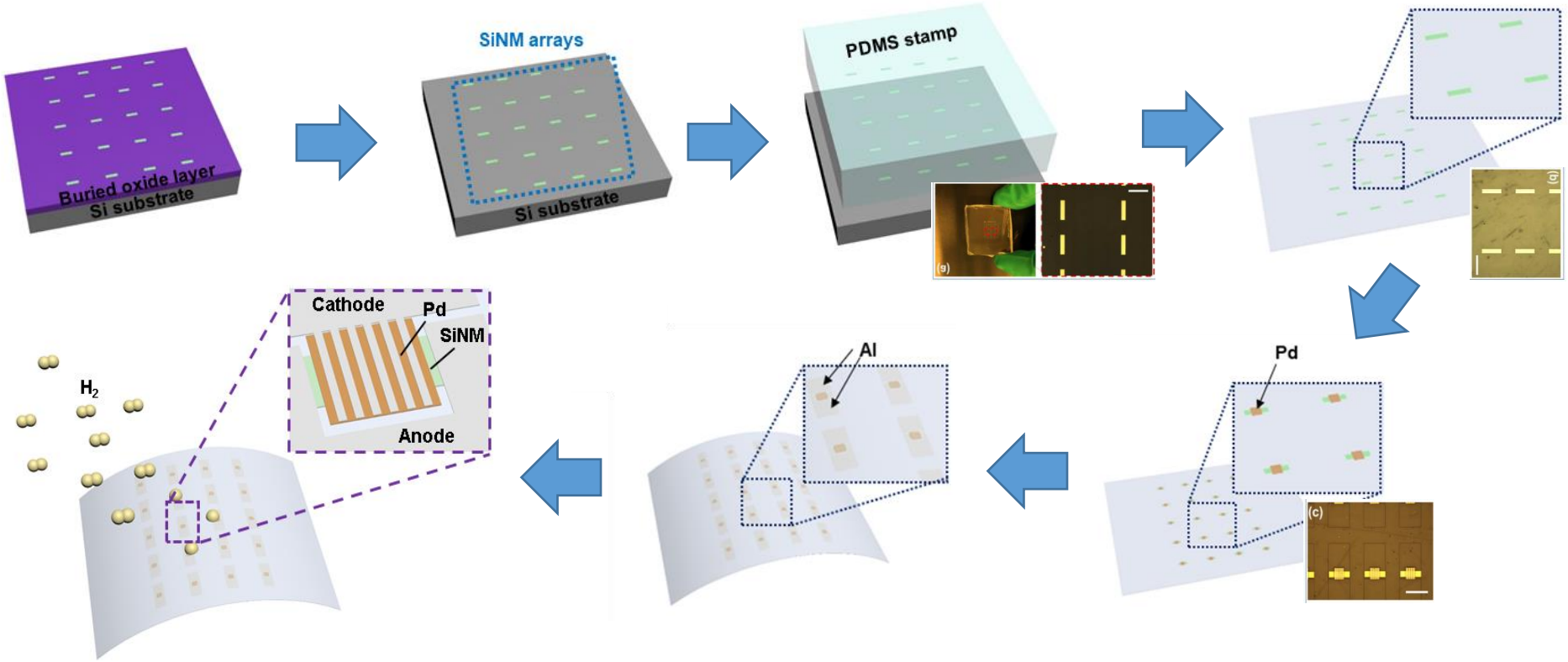


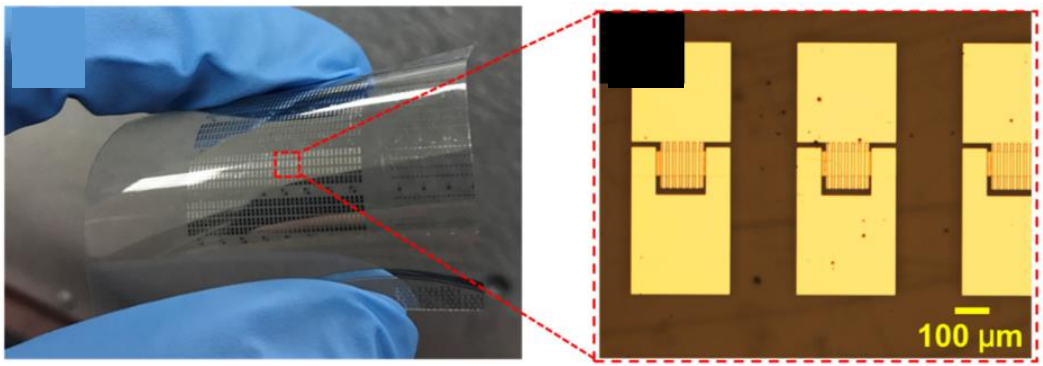
Reduced Si thickness

Low standby power consumption



03 Fabrication Process

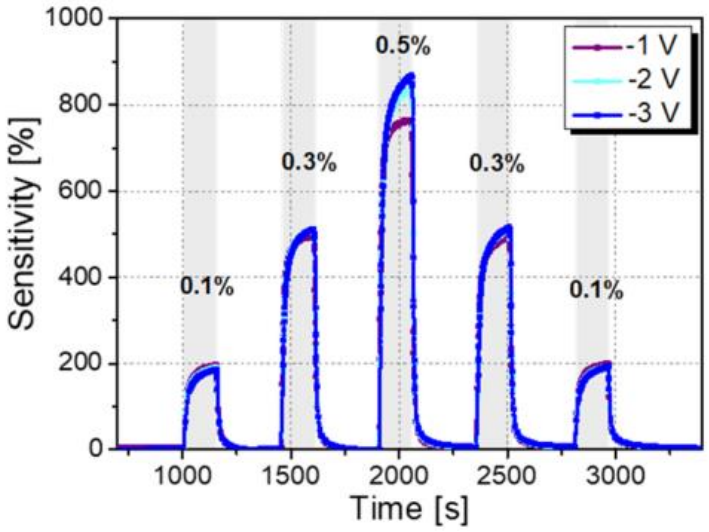


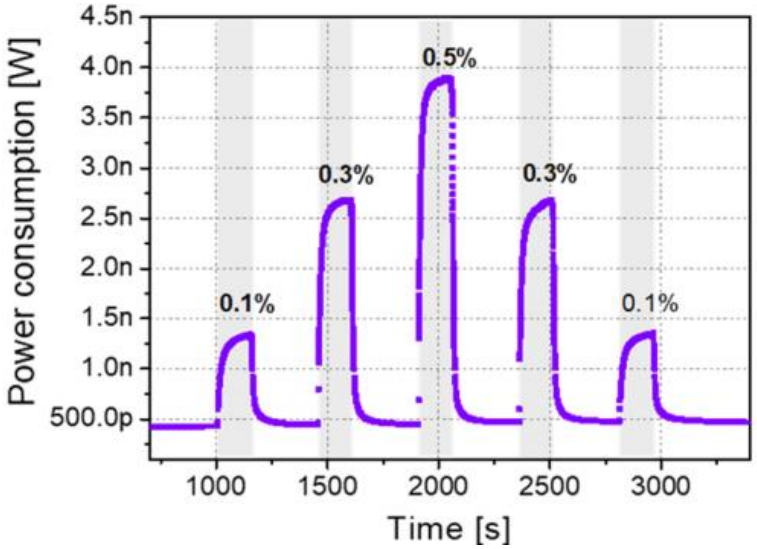


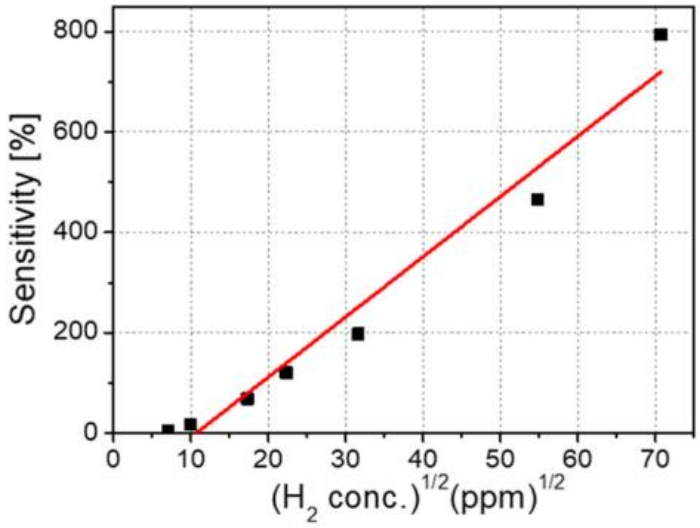
- ✓ **Excellent mechanical properties**
- ✓ **Low thermal budget (< 110 °C)**
- ✓ **Applicable to wafer-scale process**

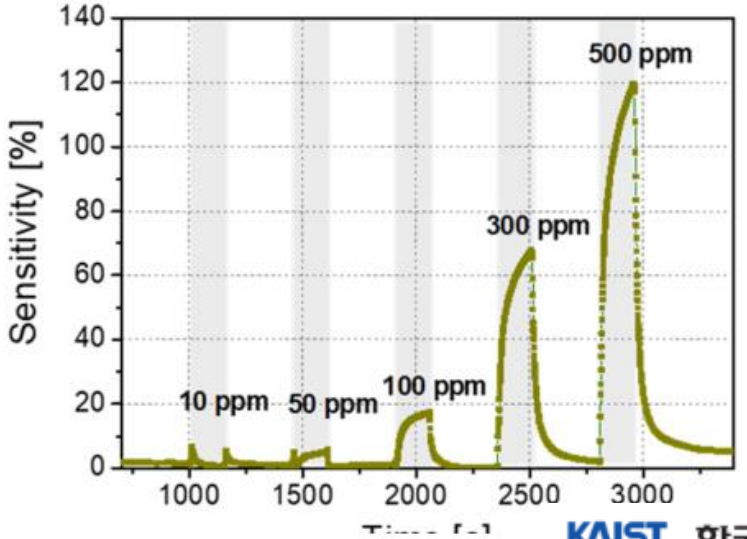
04 Hydrogen Sensing Experiment 1

- **High Sensitivity (> 700% @ 0.5% H_2 concentration) and Fast Response Time (τ_{10-90}= 22s)**
- **Good Linearity (R^2 > 0.98) and Low Limit of Detection (50 ppm, limited by MFC)**



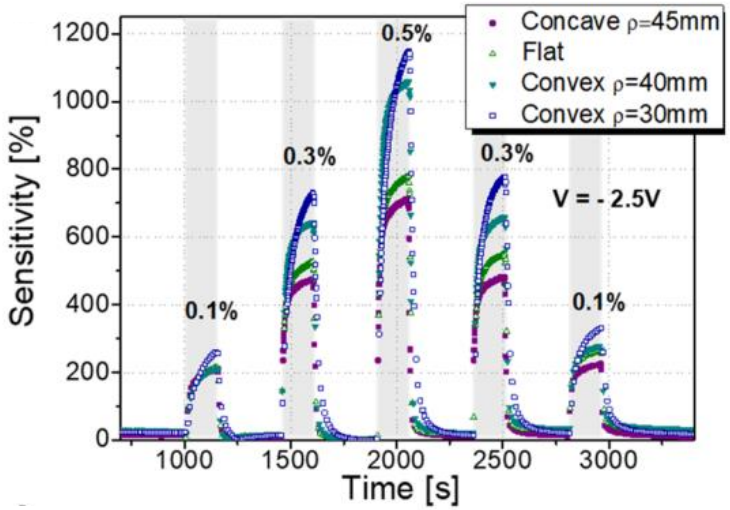


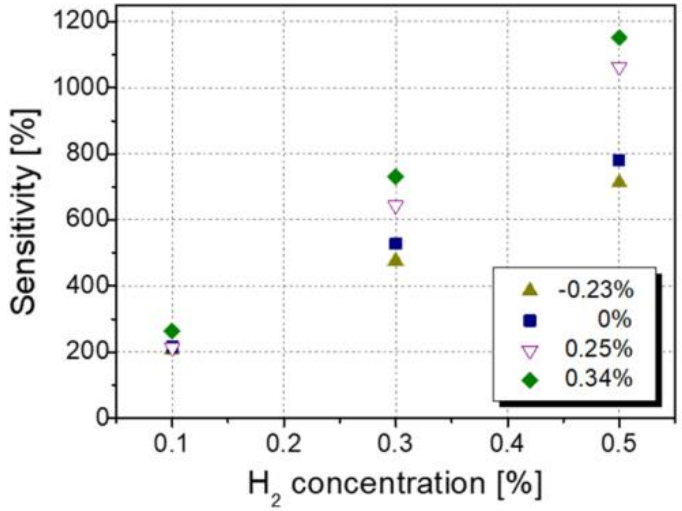


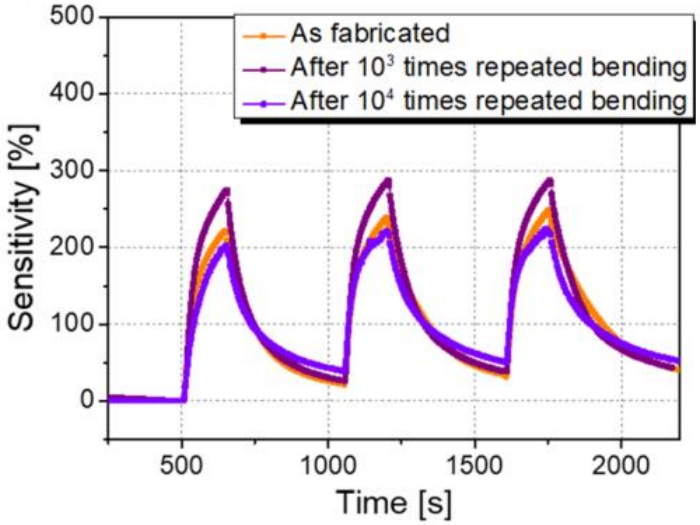


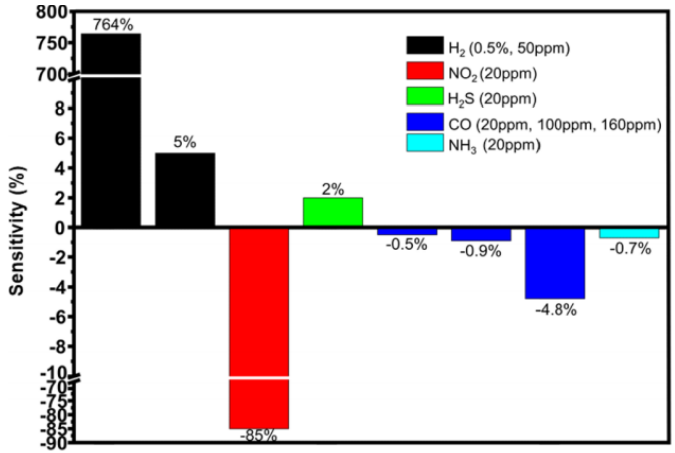
05 Hydrogen Sensing Experiment 2

- **Minor Increased Sensitivity under Tensile Strain (Piezoresistive property of SiNM)**
- **Good Reliability under Repeated Bending and Selectivity to H_2 among Various Test Gases**









06 Conclusion

- Flexible Pd/Si Schottky diode-based H_2 sensor was demonstrated using SiNM transfer on a plastic substrate.
- The sensor shows high H_2 sensitivity and fast response time
- A repeated bending test was also performed to test its mechanical durability as a flexible sensor, and high sensitivity and stable device performance were maintained after 10^4 times of repeated bending.
- The sensor fabrication process is applicable to wafer-scale.
- In conjunction with other types of sensors, the Pd/SiNM diode H sensor with a simple fabrication process would be useful in the future flexible/wearable electronics.