Gas sensing effects on $\text{In}_2\text{O}_3$ -CNT nanocomposites based FETs

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Why gas sensor and how it works

Need of gas sensor

- NO₂ is dangerous to human and creatures
- Need of accurate, highly selective NO₂ sensor arises

Gas sensing mechanism

① Output resistance of the device changes when a particular gas is adsorbed on the sensing element from the surroundings

$$\Delta R = \left(\frac{R_{\text{gas}} - R_{\text{air}}}{R_{\text{air}}}\right) \times 100$$

② Adsorbed gas molecules desorb from the sensor surface when the gas disappears and the sensor regains its original resistance

[Innovative NRG]

[Mittal2014]
Motivation

Good gas sensor properties:
- High sensitivity, selectivity, recovery behavior and fast response time

Gas sensing behavior on bare SWNT
- High sensitivity and selectivity
- Poor recovery behaviors after NO\textsubscript{x} exposure for SWCNT gas sensors

Hetero-structure of cubic phase of In\textsubscript{2}O\textsubscript{3} SWNT
- Hydrothermal growth for enhanced gas sensing properties
- Stable reversible behaviors after NO\textsubscript{x} exposure
- Improved recovery behaviors

According to high gas sensing property of In\textsubscript{2}O\textsubscript{3}-SWNT, gas sensor based on In\textsubscript{2}O\textsubscript{3}-SWNT will be better than bare SWNT.
Experimental Details

Synthesis of hetero-structure

- Prepared by one step hydrothermal synthesis method
- Heterojunction was observed by SEM analysis

Fabrication of gas sensor

- Sensors fabricated by drop-casting the solution containing the In$_2$O$_3$ SWNT on channel area

Elemental composition of Indium Oxide

(a) (b) (c) (d) (e) (f)
Physical mechanism in heterostructure $\text{In}_2\text{O}_3$ CNT

Heterojunction effect of $\text{In}_2\text{O}_3$

Heterojunction make larger band bending

It adsorb more electron gas and contribute improvement on recovery behavior
Result

Recovery behavior

**Improved recovery behavior** => *Same result with theory*
Results

**Hole donation of NO₂ lead larger shift of threshold voltage**

- Threshold voltage shifts increase with NO₂ concentration
- Gas sensor can respond in low concentration
Conclusion

• The extracted shift of threshold voltages were different with concentration of NO₂ gas (effect of hole donation)

• Hetero-junction on In₂O₃ -CNT improved recovery behavior

• Gas sensor even expected to response at small amount of NO₂ gas, because minimum shift of threshold voltage was enough high.