Fabricating Solid State Gas Sensors by Aerosol-based Techniques

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Motivation

- **Gas Sensors**
  - Emissions control and safety
  - Diagnostics

- **Aerosol-based Techniques for Synthesizing Nanomaterials**
  - Good control over particle size, morphology and composition
  - Tools for assembling nanostructures
Nanoparticles Synthesis in the Gas Phase

- **Evaporation/Condensation**
  - Tube Furnaces
  - Spark Discharges
  - Glowing Wires

- **Solution Spray**
  - Atomization
  - Electrospray

- **Flame Synthesis**
H₂ Sensor base on Pd Nanomaterials
Fabrication of a Pd-based Nanomaterials

Glowing Wire Aerosol Generator

Pd Aerosol

Aerosol Focusing Lens

Pd Nanoparticle-wire Sensor

Ar
Structure of the Pd-based Nanomaterial
Structure of the Pd-based Nanomaterial
Stabilization of the Structure

Current (A) vs. Voltage (V)
Response of the Pd Nanoparticle H$_2$ Sensor
Sensitivity of the H$_2$ Sensor

- H$_2$: 93ppm, 73ppm, 2.5ppm, 780ppb
- Ar: 210ppm, 14ppm, 195ppb

Normalized Conductivity vs. Time (s)
Electrospray Deposition

Precursor Solution

High Voltage

Heated Surface
Temperature-dependent Morphology Changes of WO$_3$ Nanostructures
Electrospray/Electrostatic Deposition

(a) Temperature gradient = Solvent evaporation = droplet shrinkage

(b) Oxidation or partial oxidation of the precursor

(c) Particle agglomeration on preferential landing areas

(d) Tree-like morphology
Growth of Nanowires

- Aluminum foil
- Silicon wafer
- Alumina
- Glass
Controlling the Growth of Nanowires

Post-deposition of KOH

Annealing
Sensitivity Measurements
**Sensitivity Measurements**

![Graph showing sensitivity measurements](image)

- Sensitivity: $\frac{R_{\text{gas}}}{R_{\text{argon}}}$
- Temperature range: 0°C to 300°C
- 10 ppm NO suboxides

The graph illustrates the sensitivity of a device to NO suboxides as a function of temperature. The sensitivity peaks at around 200°C, indicating optimal performance in this temperature range.
Preliminary Tests

WO3 @ 350 °C

Resistence vs. Time (min)

Air

0 ppm
5 ppm
10 ppm
5 ppm
2.5 ppm
1 ppm

0 50 100 150 200
Summary

• Aerosol Techniques for Synthesizing Nanostructures Materials for Gas Sensors
  • Nanoparticle Generation
  • Nanomaterial Assembly
• H₂ Sensor
  • Synthesis of Pd Nanostructures
  • Sintering by Annealing
• NOₓ Sensor
  • Synthesis of WO₃ Nanostructures
  • Decorate with Nanowires for Enhanced Performance…
The Catch and Outlook

• Catch
  • Analyte in high purity Ar, N₂, or synthetic Air
  • If we use ambient air, the story changes completely

• Further work
  • Selectivity
  • Repeatability (long term)
  • Sensitivity (?)