NanoAffix Science, LLC

Milwaukee, Wisconsin

Dr. Yale Wang
Research Scientist

A low-cost handheld sulfur dioxide tester with a hybrid nanomaterials-based sensor chip

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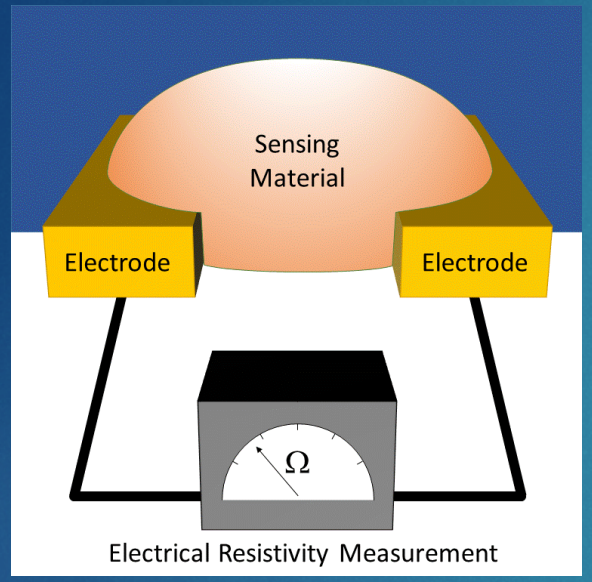
Accurate Affordable Analysis

Chemiresistive Gas Sensors



Electrical Resistivity Measurement

Technology	Metal oxide semiconductor	Electrochemical	Infrared	eNose (sensor arrays)
Sensitivity / LOD	Sub-ppm	100 ppb-ppm	ppm (LED based), ppb (laser based)	Sub-ppm
Selectivity	Not good	Better than MOS	Good	Better than EC and MOS
Price	< $5	$5-20	$20-150	N/A
Miniaturisation	MEMS	Printed technology	On process	MEMS
Suitability for multiple gas detection	No	Only for gases without overlapping	Need to change spectrum (array)	Yes
Dimensions (W x L x H mm)	2 x 3 x 1	20 x 20 x 4	26 x 21 x 7	Depending on different technologies
Power consumption	< 1 mW	10-50 µW	~ 10 mW	Depending on different technologies

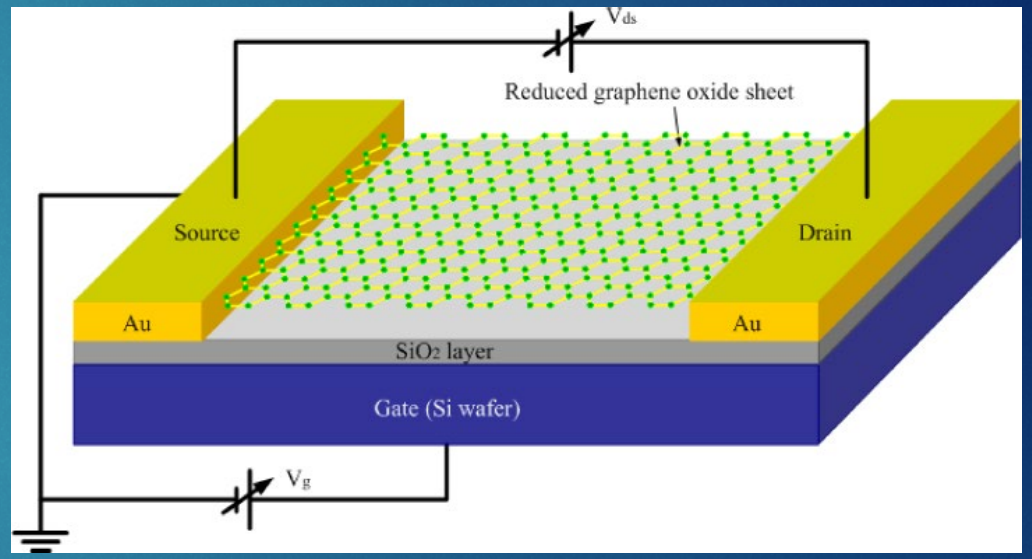
Excellent
Acceptable
Bad

IDTechEx Research

- Chemiresistive sensors provide the advantages of ease in fabrication, simplicity of operation, and advances in miniaturization.
- Traditional chemiresistive sensors (Metal oxide-based) suffer from poor selectivity and high operating temperature.

RGO-based Chemiresistive Sensors

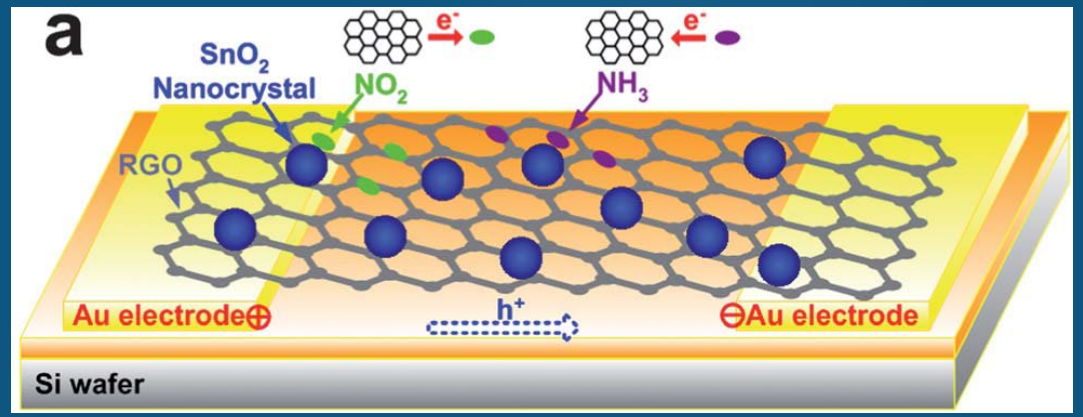
- Graphene
  - Atomic 2D-layer structure, high specific surface area
  - Extremely high carrier mobility, low electrical noise
- Reduced graphene oxide (RGO)
  - Graphene derivatives with similar 2D-layer structure
  - The presence of surface groups enhances the gas adsorption
- RGO-based chemiresistive sensors
  - Advantages: low cost, fast response, low operating temperature
  - Challenges: poor selectivity, low sensitivity



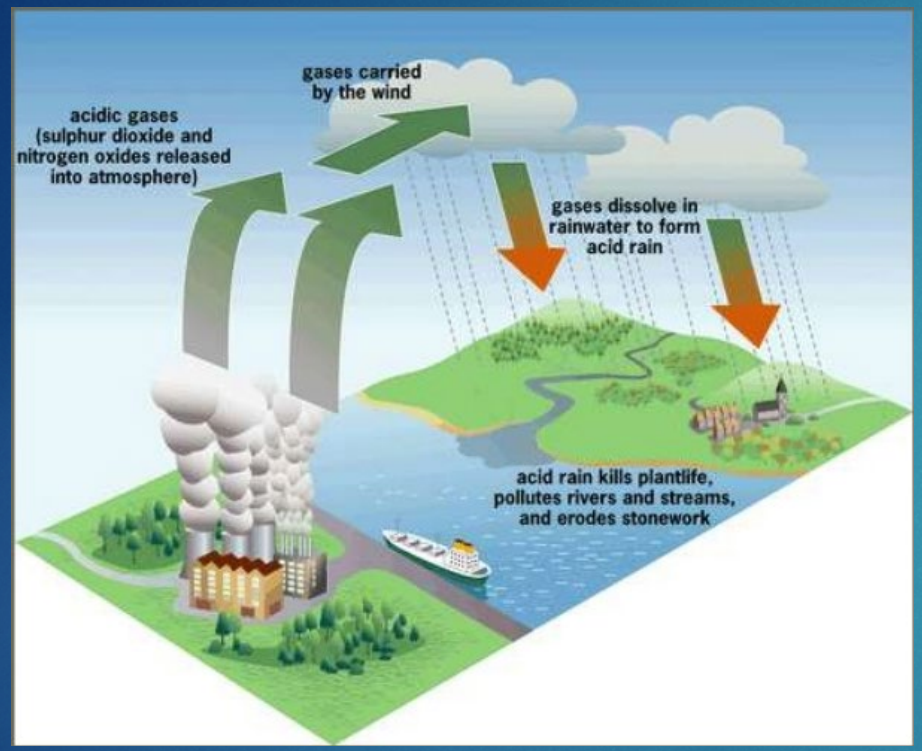
Reduced graphene oxide for room temperature gas sensors. Nanotechnology 2009, 20 (44), 445502

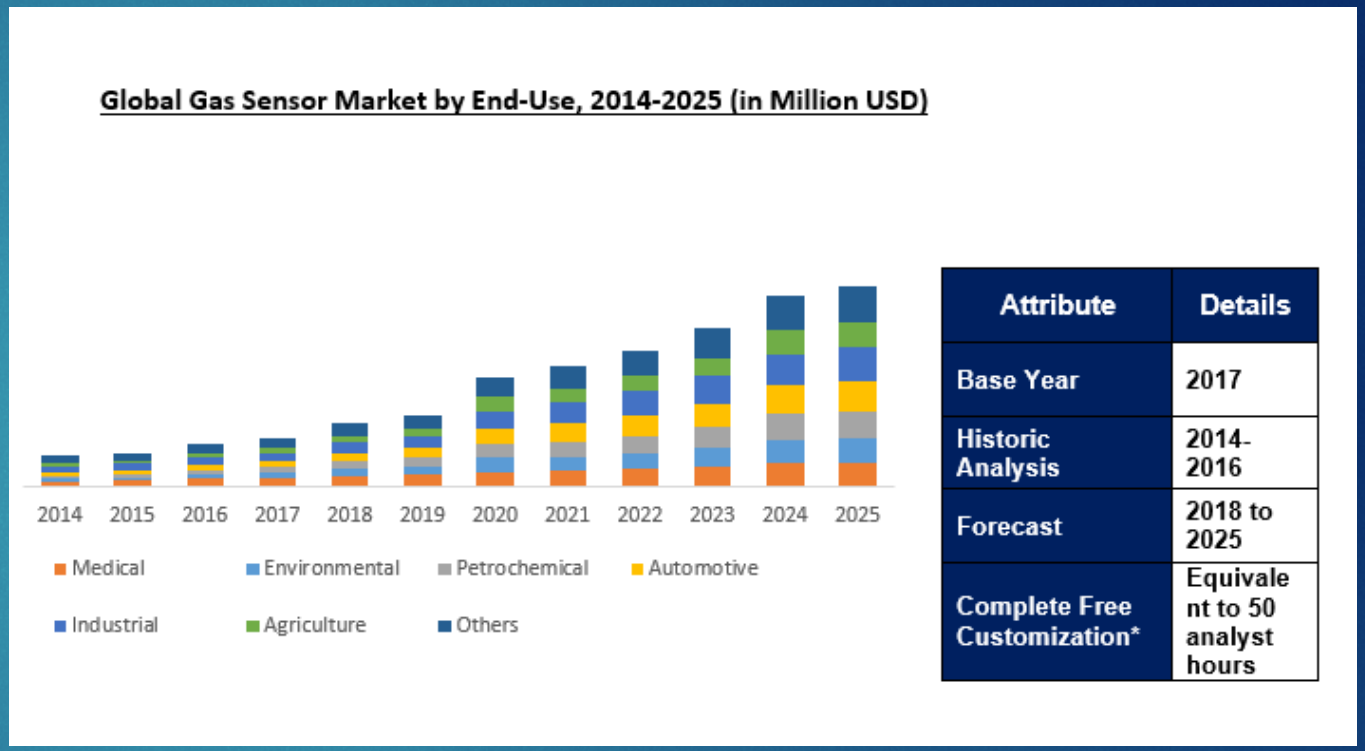
RGO-based Heterostructures for Gas Sensing

- RGO-based heterostructures
  - Surface groups enable further functionalization
  - An effective method to enhance the sensing properties
- Metal Oxide Semiconductor (MOS) decorated rGO-based heterostructures
  - Combination of high electronic conductivity and high sensitivity
  - Reduced operating temperature
  - Open for further functionalization (noble metal etc.)



Need for Sulfur Dioxide Monitoring





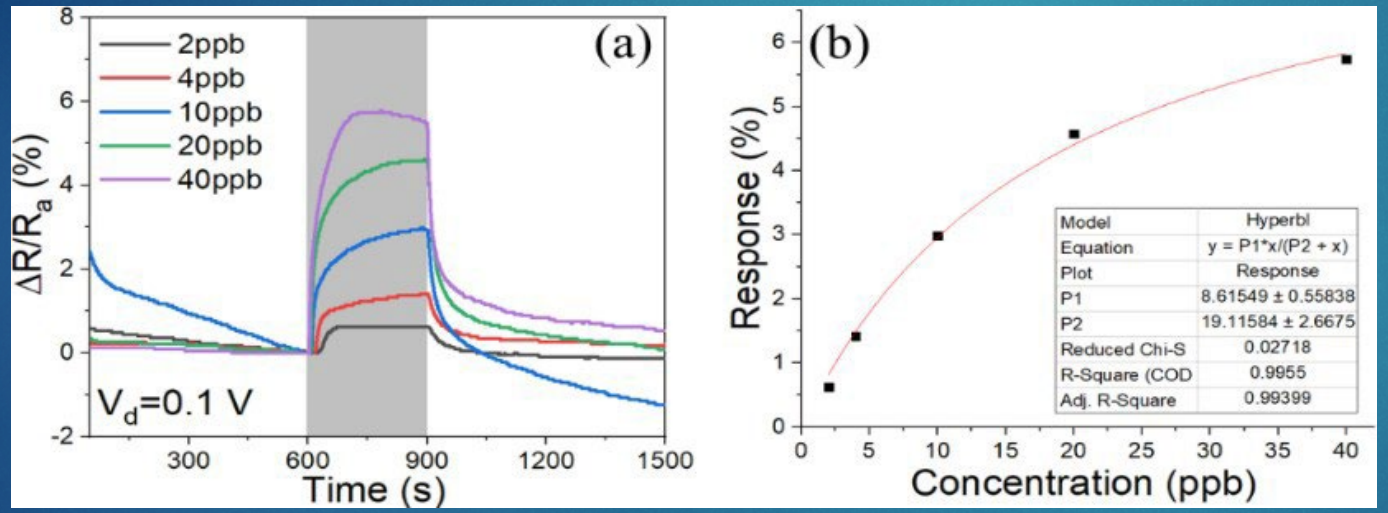
Attribute	Details
Base Year	2017
Historic Analysis	2014-2016
Forecast	2018 to 2025
Complete Free Customization*	Equivalent to 50 analyst hours

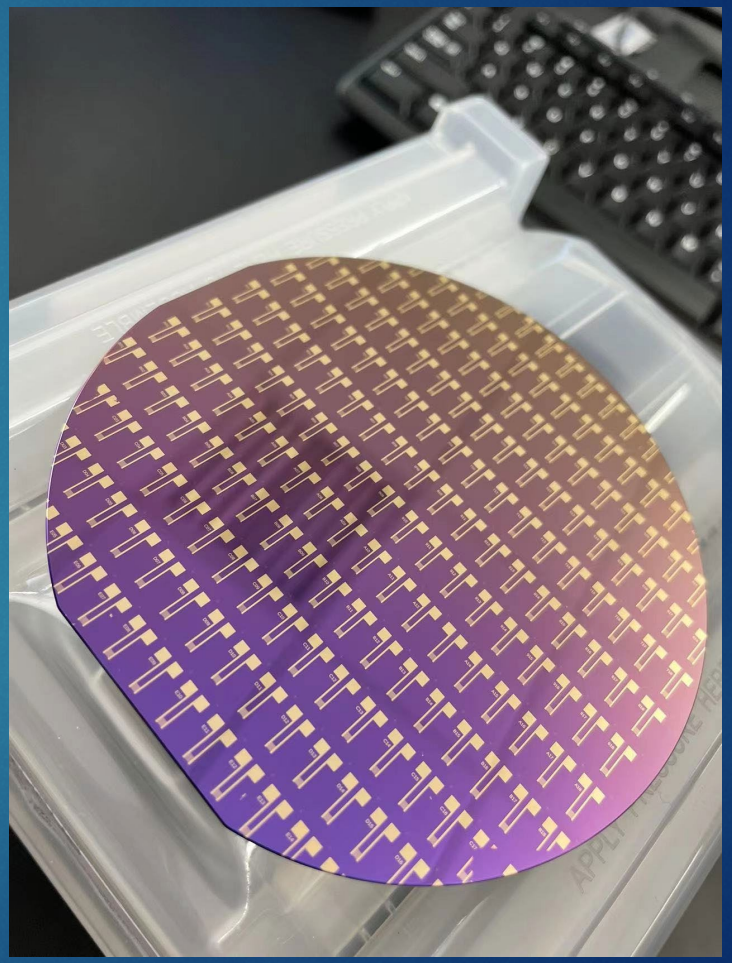
- One of the most common air pollutants
- The market for gas analyzers is estimated to reach $4.7 billion by 2025 and expected to continue to grow at a rate of 3.8%

https://pmgbiology.com/tag/sulphur-dioxide/, https://www.govinfo.gov/content/pkg/FR-2019-03-18/pdf/2019-03855.pdf

Competitive Advantage

- **Faster, Better, and Less Expensive Analysis**
  - Portable and Onsite results in minutes
  - Improved Limit of Detection (LOD)
  - Cost savings





Product Specifications

- Sensitivity
  - Down to 1 ppb SO_2
  - EPA standard is 75ppb
- Response time
  - Test requires less than 2 minutes
- Power consumption
  - Lithium-ion battery

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Acknowledgement

EPA SBIR Phase I
March 2020 – August 2020

EPA SBIR Phase II
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Thank you!
info@nanoaffix.com

Yale Wang
ywang@nanoaffix.com

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