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REVIEWER'S REPORT

Manuscript No.: **IJAR-53231** Date: 09-08-2025

Title: Comparative and Machine Learning-Driven Analysis of Reduced Graphene Oxide–Polymer Gas Sensors:Materials and Sensitivity Trends

Recommendation:
Accept as it is

Rating	Excel.	Good	Fair	Poor
Originality		√		
Techn. Quality		√		
Clarity		√		
Significance		√		

Reviewer Name: Dr. Manju M **Date:** 09-08-2025

Reviewer's Comment for Publication.

1. The combination of rGO and conducting polymers effectively enhances gas sensing performance through complementary properties, marking a key advancement in hybrid material design.
2. These composites show strong potential for detecting diverse toxic gases, enabling wide-ranging applications in environmental, healthcare, and security domains.
3. The integration of ML tools significantly improves sensor selectivity, data analysis, and predictive design, driving the evolution toward intelligent sensing systems.
4. Performance variability due to inconsistent fabrication methods highlights the urgent need for standardized, scalable manufacturing protocols to ensure reproducibility and commercial viability.
5. Issues such as humidity sensitivity, device stability, and long-term reliability must be addressed before these sensors can achieve widespread real-world deployment.

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Detailed Reviewer's Report

1. **Objective of the work:**

To develop and optimize reduced graphene oxide–polymer composite-based gas sensors that combine high sensitivity, selectivity, environmental stability, and low power consumption, enabling scalable fabrication of flexible, wearable, and intelligent sensing platforms for real-time gas detection across diverse applications.

2. Synergistic Material Integration of rGO and Polymers

Reduced graphene oxide (rGO) combined with polymers creates a composite that leverages the high electrical conductivity, large surface area, and mechanical strength of rGO alongside the chemical tunability, flexibility, and processability of polymers. This synergy results in materials that are both highly sensitive to gas molecules and adaptable to diverse sensing requirements.

3. Superior Gas Sensing Performance at Room Temperature

rGO–polymer composites demonstrate excellent gas sensing at room temperature, eliminating the need for external heating elements. The intrinsic electrical conductivity of rGO and the selective binding properties of polymers enable high sensitivity and rapid response times, making these composites energy efficient and suitable for portable devices.

4. Polymer Chemistry Enhances Selectivity and Functionalization

Polymers such as polyaniline (PANI), polypyrrole (PPy), and PEDOT:PSS provide specific functional groups and doping capabilities that increase interaction with targeted gas molecules. This chemical versatility allows for tailoring sensor selectivity without compromising sensitivity, facilitating detection of gases like NH_3, NO_2, VOCs, and explosives.

5. Fabrication Techniques Impact Morphology and Sensor Performance

Methods including solution casting, in-situ polymerization, electrospinning, spin coating, and layer-by-layer assembly **i**nfluence the composite's morphology, active surface area, and film uniformity. Optimizing these techniques is critical to controlling sensor reproducibility, sensitivity, and response dynamics.

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6. Challenges in Environmental Stability and Robustness

Sensors face performance degradation due to environmental factors like humidity, temperature variations, and contaminants. Addressing these challenges requires material engineering and device-level solutions to ensure reliable long-term operation.

7. Device-to-Device Variability and Reproducibility

A key limitation is inconsistency in sensor output across different batches, attributed to fabrication variability and material heterogeneity. Advancing standardized production protocols and quality control measures is essential for industrial-scale manufacturing and commercialization.

8. Integration into Flexible and Wearable Sensor Platforms

The mechanical flexibility and lightweight nature of rGO–polymer composites enable development of flexible, stretchable, and wearable sensors. Such devices are ideal for real-time, on-body environmental and health monitoring, supporting emerging trends in personalized sensing technologies.

9. Multi-Sensor Arrays for Enhanced Selectivity

Deploying arrays of sensors with different polymer functionalizations and rGO compositions allows pattern recognition of complex gas mixtures. Unique response patterns from these sensor arrays improve discrimination and identification of multiple gases simultaneously.

9. Machine Learning for Advanced Data Interpretation and Sensor Design

Machine learning algorithms analyze complex sensor outputs, enhancing gas identification accuracy and providing insights into performance-determining factors such as limit of detection (LOD) and gas type. ML also assists in rational material screening and sensor optimization by predicting promising rGO–polymer combinations.

10. Real-World Application Prototypes and Use Cases

Prototypes based on rGO–polymer composites have been demonstrated for applications such as environmental pollutant detection, industrial safety monitoring, toxic gas sensing, and explosive detection. Their rapid response, high sensitivity, and portability make them practical for field deployment.

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11. Data-Driven Design Guidelines and Visualization Tools

Compilation and statistical analysis of published sensor data support data-driven sensor design**,** allowing researchers to identify performance trends and optimal materials for target gases. Visualization tools like heatmaps and radar charts facilitate intuitive comparison of different sensor systems.

12. Future Outlook: Towards Scalable, Intelligent Gas Sensing Systems

Ongoing research focuses on improving scalability, reproducibility, and environmental robustness, while integrating sensors with IoT networks, flexible electronics, and smart algorithms**.** This transition heralds the development of autonomous, adaptive sensing platforms for broad industrial, environmental, and healthcare applications.

14. Significance of the work:

- The integration of rGO with polymers significantly improves gas sensor sensitivity, selectivity, and response speed at room temperature, enabling efficient and accurate detection of a wide range of gases without the need for complex heating elements.
- The development of flexible, wearable rGO–polymer composite sensors combined with machine learning and data-driven design paves the way for scalable, low-power, and intelligent gas monitoring systems suitable for real-time environmental, industrial, and health applications.