International Conference on
PRecision Engineering and Sustainable Manufacturing

PRESM 2023

July 16 Sun **– 21** Fri, 2023

Bankoku Shinryokan,
Okinawa, Japan

Proceedings

http://www.presm.org

ISSN 2635-7887

Organizer

Korean Society for Precision Engineering (KSPE, Korea)

Co-Organizers

The Japan Society for Precision Engineering (JSPE, Japan)

Taiwan Society for Precision Engineering (TSPE, Taiwan)

Contents

Early Detection of Metabolic Disorders using n-rGO-ZnO Hollow Spheres NO_2 Breath

Arunkumar Shanmugasundaram[1)], and Dong-Weon Lee[1,2)*]

[1)]School of Mechanical Engineering, Chonnam National University, Gwangju, 61186, Republic of Korea,

[2]Center for Next-generation Sensor Research and Development, Chonnam National University (* mems@jnu.ac.kr)

Abstract

The detection of metabolic disorders, such as diabetes, liver, and lung disease, can be achieved through the analysis of volatile organic compounds (VOCs) present in a human's breath. Among several VOC biomarker compounds, NO_2 has been considered as a promising biomarker for the early diagnosis of several metabolic disorders. Over the years, several metal oxide-based breath sensors have been proposed for the detection of NO_2. However, the practical feasibility of those sensors is limited due to their poor sensitivity and high operating temperature. Additionally, the complexity of the environment, including high humidity and several interfering gases in the human's breath, affects the sensor's performance. Sensing NO_2 at the parts per billion (ppb) level remains a significant challenge for the reported gas sensors. In this study, we introduce a novel NO_2 breath sensor based on nitrogen-doped reduced graphene oxide-ZnO hollow spheres (n-rGO-ZnO) for the detection of NO_2 levels in human breath with high sensitivity and selectivity. The fabricated sensors are characterized in detail through different analytical techniques for their crystal structure, morphologies, chemical and physical properties, and the findings are consistent with each other. The proposed sensor shows a two-fold and five-fold increase in sensitivity compared to the sensors based on bare rGO-ZnO and ZnO hollow spheres, respectively. The proposed n-rGO-ZnO sensor exhibits excellent sensitivity as low as 100 ppb at 125 °C. An assessment of the efficacy of the proposed sensor for the detection of metabolic disorders through NO_2 sensing analysis in exhaled breath demonstrated that the n-rGO-ZnO hybrid nanocomposite-based e-nose sensor arrays produced distinct signals for healthy and simulated breaths. The signals did not overlap, indicating that healthy and unhealthy breaths could be accurately distinguished. Therefore, n-rGO-ZnO-based sensors represent a viable solution for screening metabolic disorders in patients and monitoring indoor NO_2 levels with ease. These non-invasive sensors offer a convenient and early detection method for metabolic disorders, enabling prompt treatment and improved patient outcomes.

Material and methods

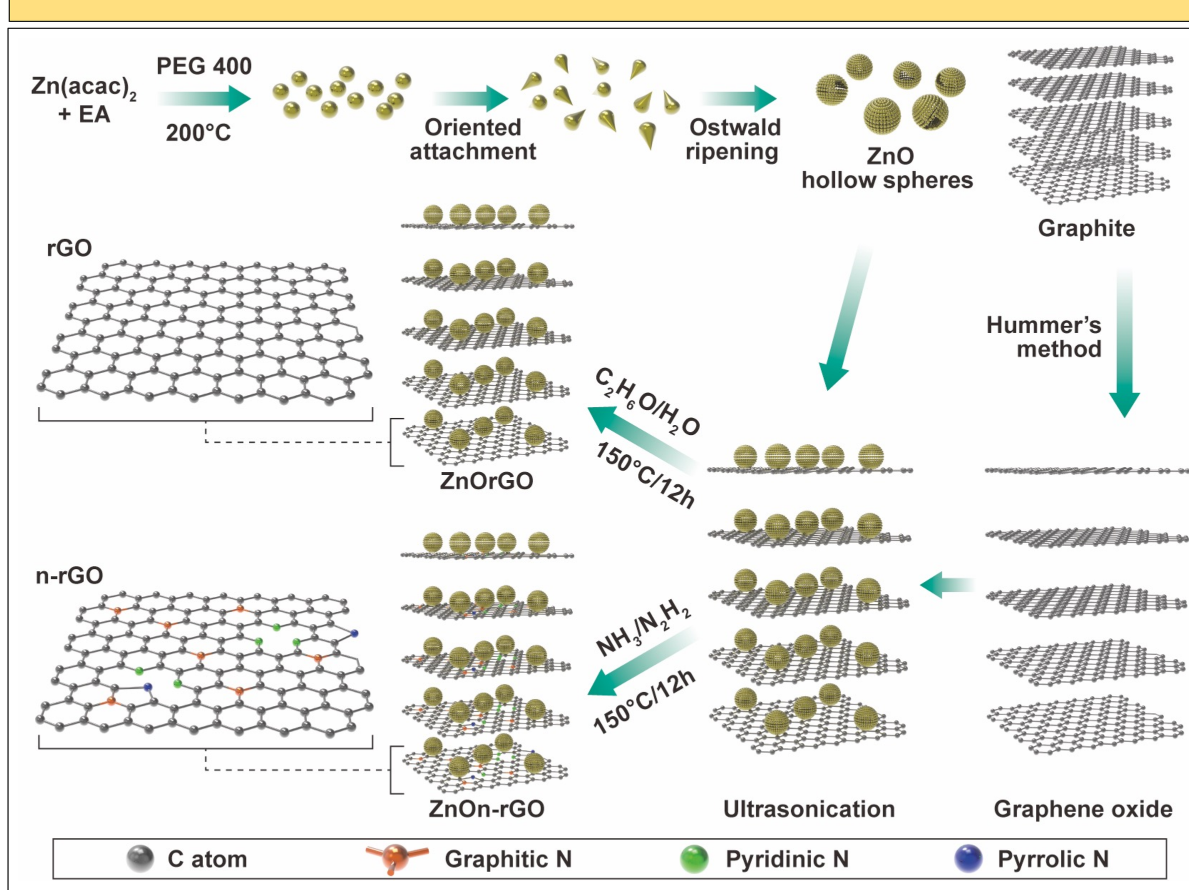

Fig. 1. Schematic shows the preparation of ZnO, rGO-ZnO, and n-rGO-ZnO hybrid nanocomposites.

Morphological analysis

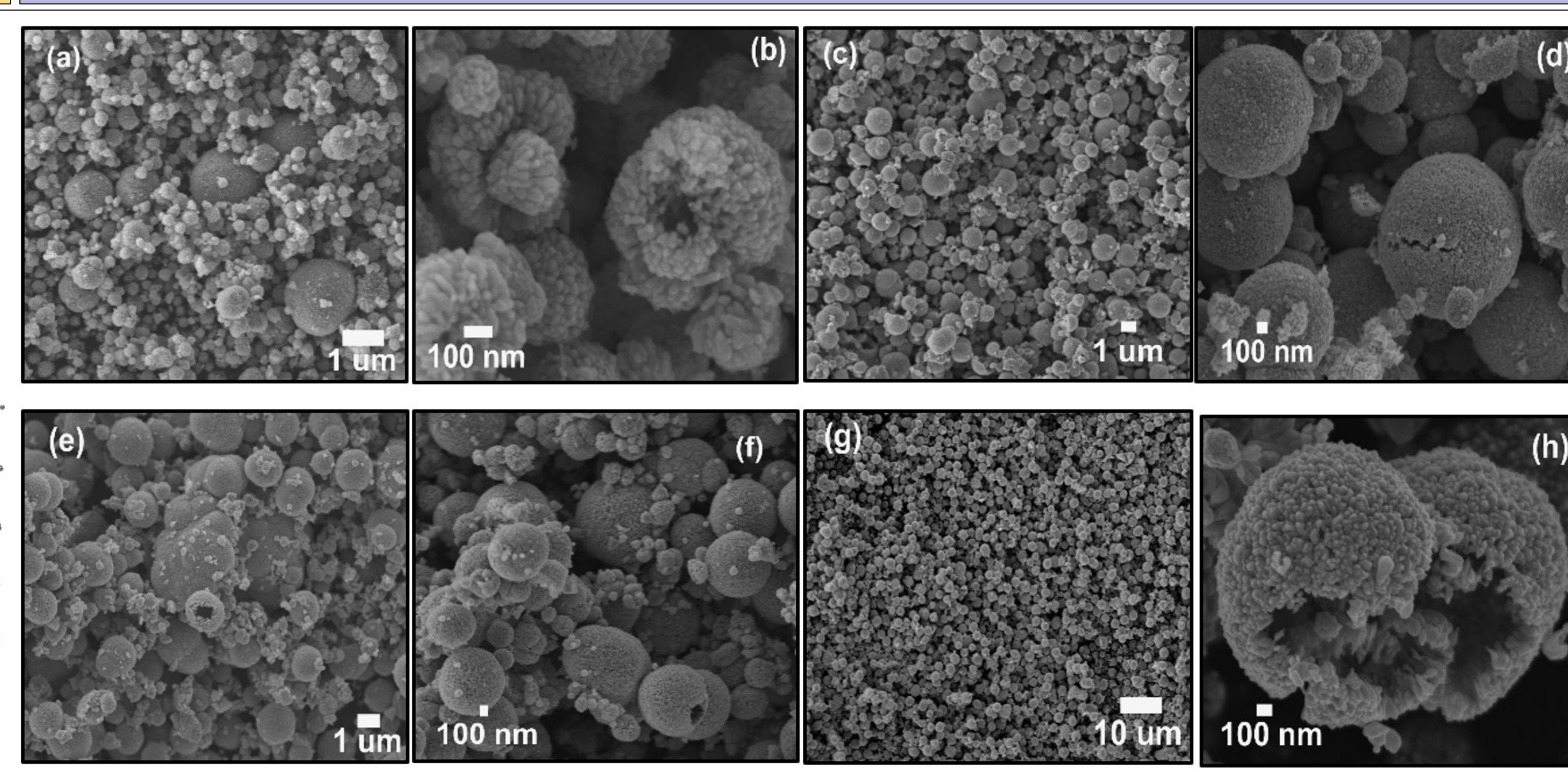

Fig. 2. Morphological analysis of the as-prepared ZnO hollow spheres at different solvothermal reaction time.

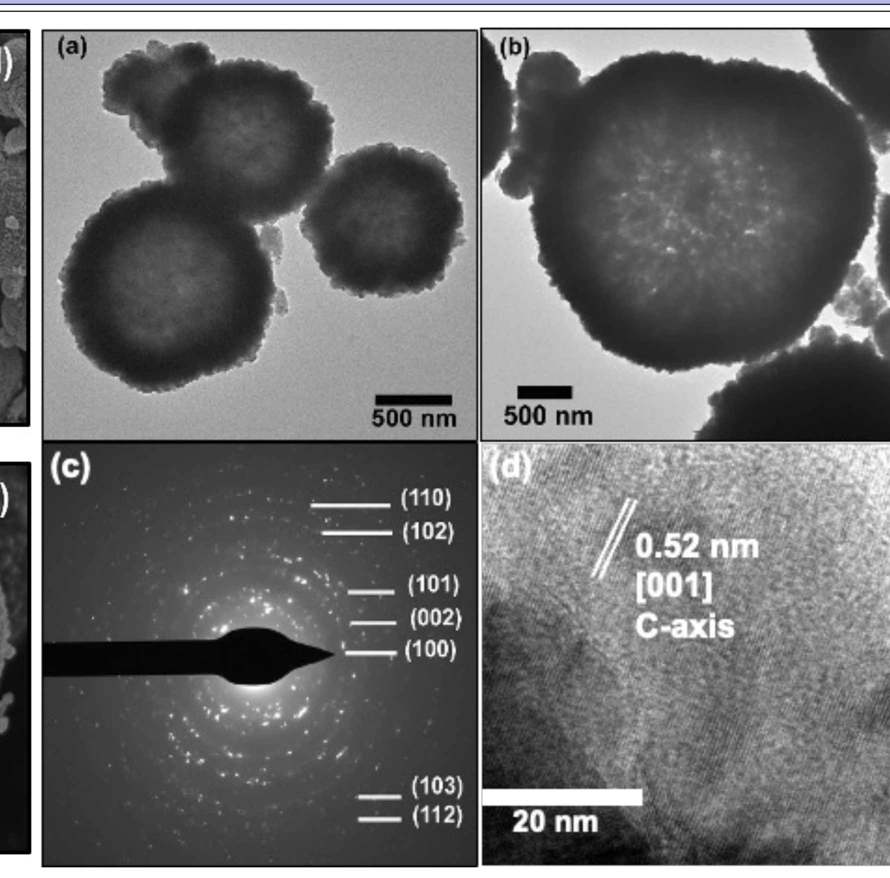

Fig. 3. TEM images of the as-prepared n-rGO-ZnO hollow spheres hybrid nanocomposites.

Crystal structure and phase purity analysis

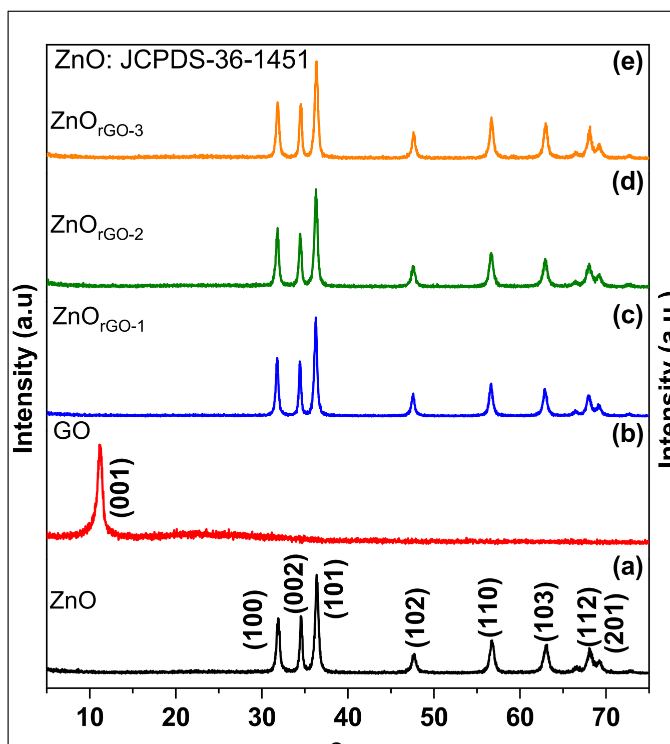

Fig. 4. Powder X-ray diffraction analysis of as-prepared materials.

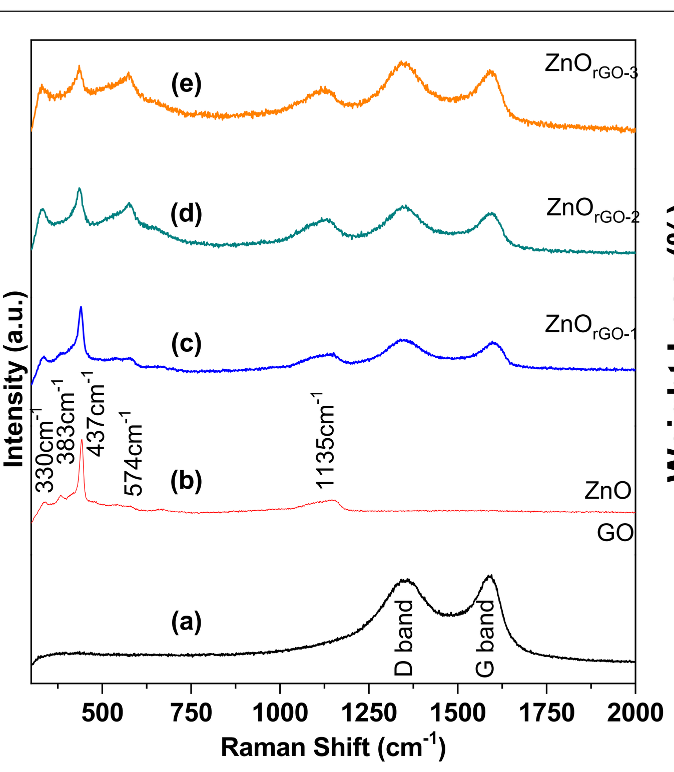

Fig. 5. Raman spectra analysis of as-prepared materials.

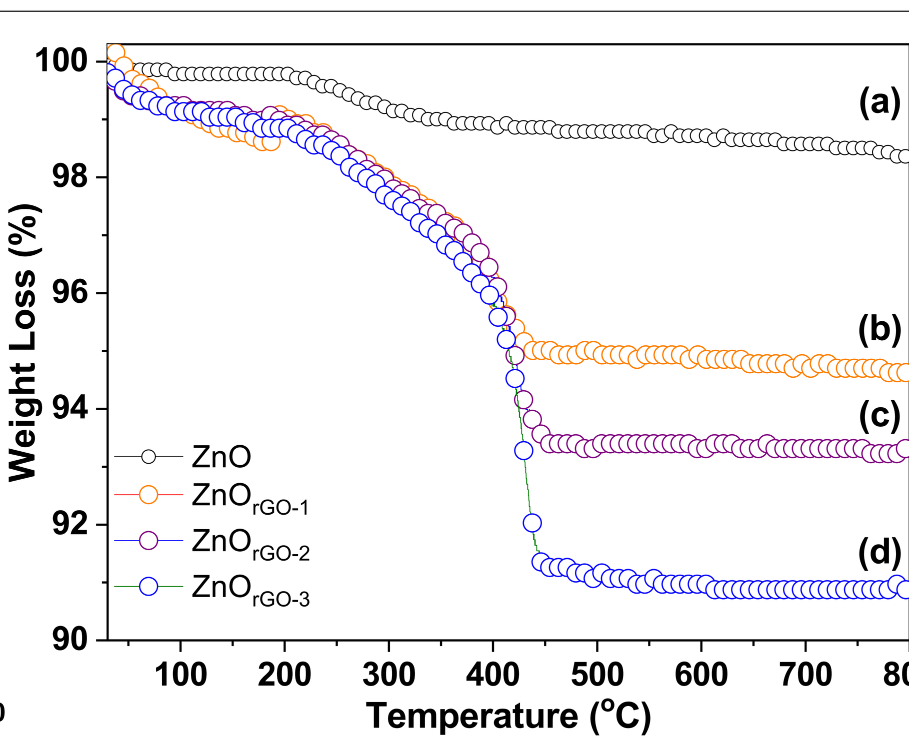

Fig. 6. Thermal gravimetry analysis of the as-prepared materials.

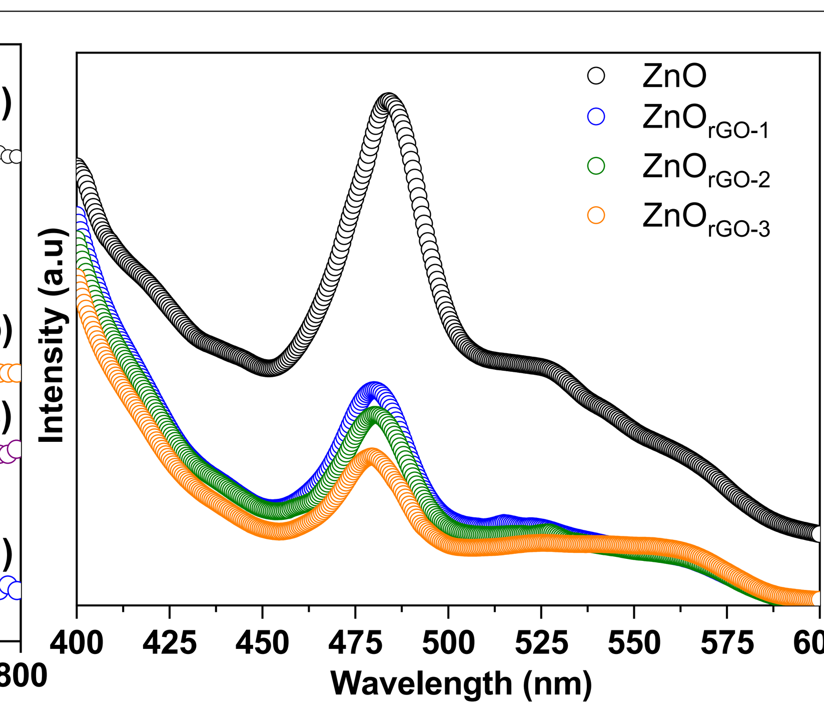

Fig. 7. Photoluminescence spectra analysis of the as-prepared materials.

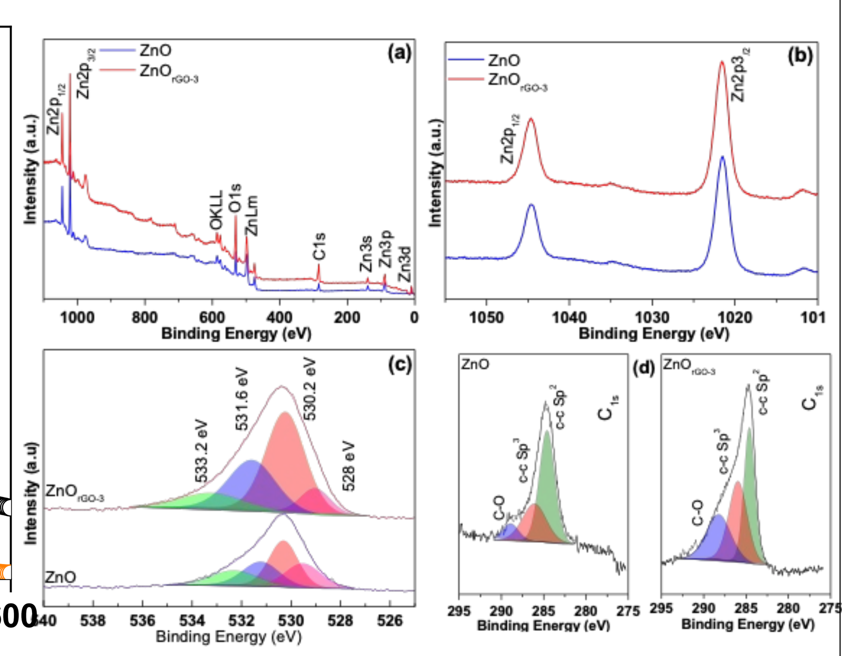

Fig. 8. XPS spectra analysis of the as-prepared ZnO hybrid nanocomposites.

Gas sensing characteristics

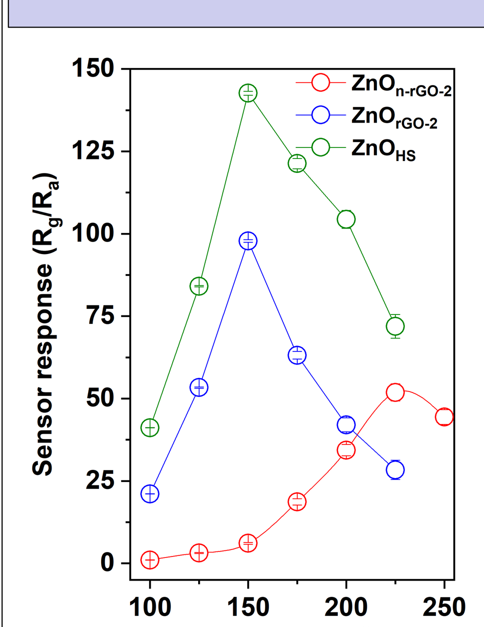

Fig. 9. Temperature dependance sensing characteristics.

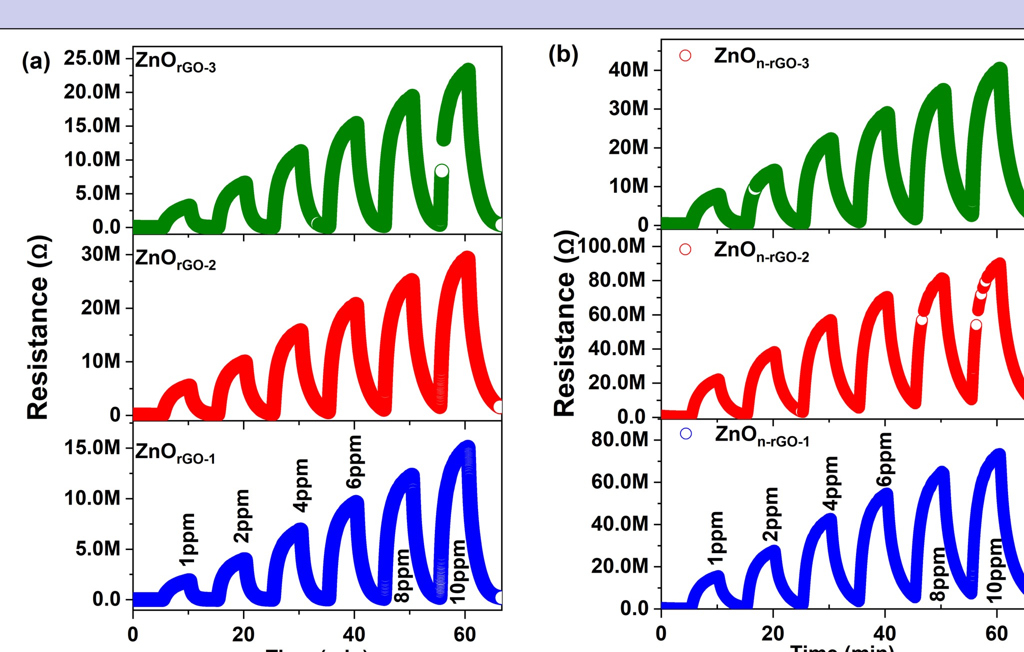

Fig. 10. Dynamic sensing characteristics of the fabricated sensor based on rGO-ZnO and n-rGO-ZnO hybrid nanocomposite at 125 °C.

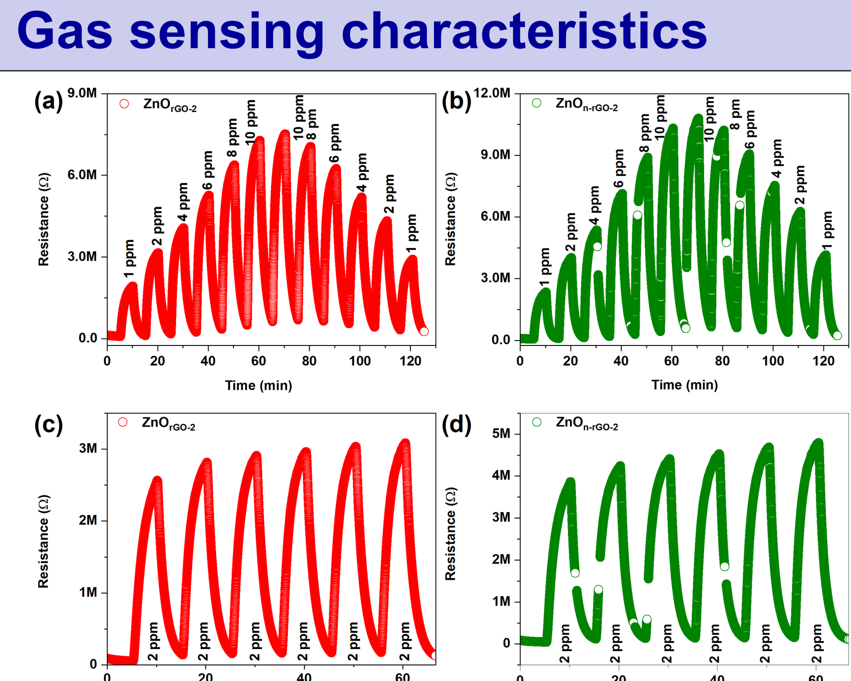

Fig. 11. Stability and reproducibility of the fabricated sensor based on rGO-ZnO and n-rGO-ZnO hybrid nanocomposite at 100 °C.

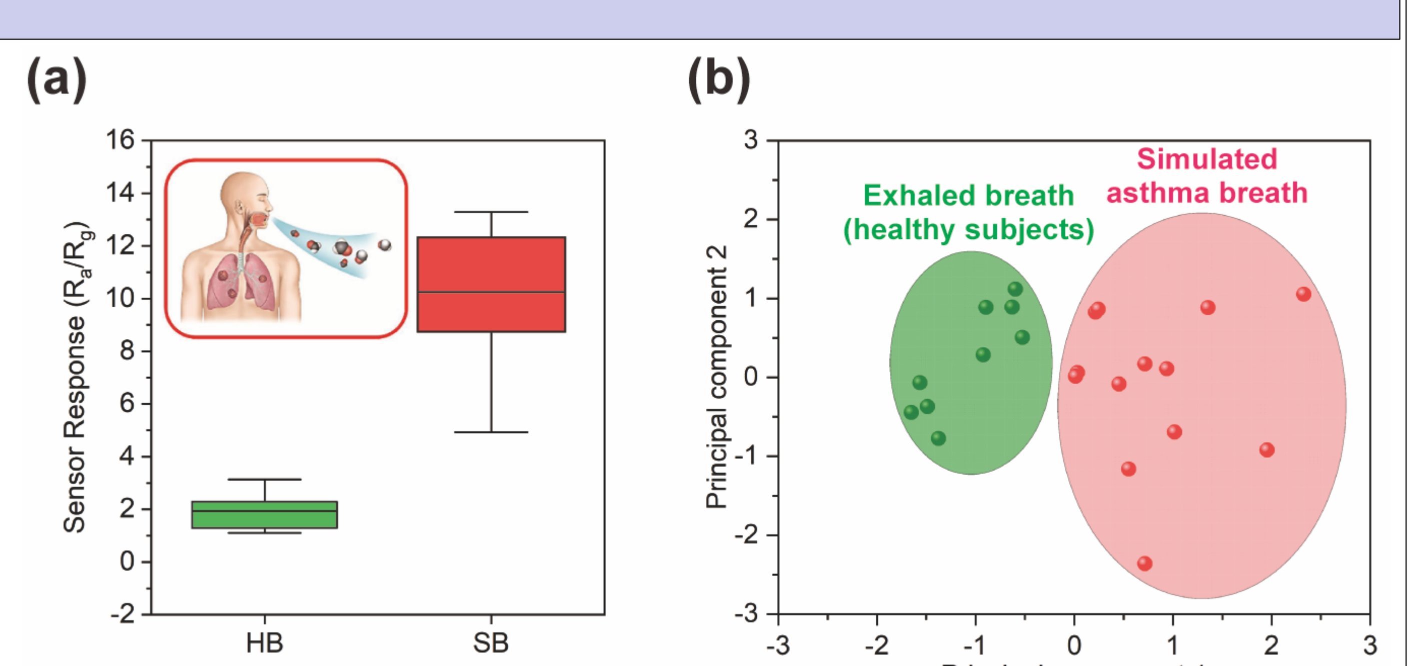

Fig. 12. Real and simulated breath sensing response of the sensor based on n-rGO-ZnO hybrid nanocomposite. Principal component analysis of the data set obtained from the sensor arrays assessing healthy subjects and simulated breath.

Conclusion

In conclusion, ZnO hollow spheres, along with rGO-ZnO and n-rGO-ZnO hybrid nanocomposites, were synthesized utilizing a facile solvothermal procedure. A thorough investigation was conducted on the fabricated sensors with respect to their NO_2 detection capabilities. The structural coherence and crystalline arrangement of the synthesized materials were verified by exhaustive materials characterization techniques, yielding corroborative results. Notably, the n-rGO-ZnO hybrid nanocomposite sensor demonstrated superior selectivity towards NO_2, as opposed to other confounding gaseous elements. The signal differentiation between healthy and simulated pathological breaths, using the hybrid nanocomposite-based electronic nose sensor arrays, was clear, thus signifying the sensor's precise ability to differentiate between salubrious and detrimental breath conditions.

Acknowledgements

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. 2020R1A5A8018367, No. 2020R1I1A1A01073562).

Early Detection of Metabolic Disorders using N-rGO-ZnO Hollow Spheres NO_2 Breath Sensor

Arunkumar Shanmugasundaram[1], **Dong-Weon Lee**[1,2,3#]

1 Department of Mechanical Engineering, Chonnam National University, Gwangju, Republic of Korea
2 Advanced Medical Device Research Center for Cardiovascular Disease, Chonnam National University, Gwangju, Republic of Korea
3 Center for Next-generation Sensor Research and Development, Chonnam National University, Republic of Korea
Corresponding Author / E-mail: mems@jnu.ac.kr

KEYWORDS: Zno hollow spheres, Nitrogen doped rGO, Breathe sensor, NO_2 sensing, Excellent sensitivity

The detection of metabolic disorders, such as diabetes, liver, and lung disease, can be achieved through the analysis of volatile organic compounds (VOCs) present in a human's breath. Among several VOC biomarker compounds, NO_2 has been considered as a promising biomarker for the early diagnosis of several metabolic disorders. Over the years, several metal oxide-based breath sensors have been proposed for the detection of NO_2. However, the practical feasibility of those sensors is limited due to their poor sensitivity and high operating temperature. Additionally, the complexity of the environment, including high humidity and several interfering gases in the human's breath, affects the sensor's performance. Sensing NO_2 at the parts per billion (ppb) level remains a significant challenge for the reported gas sensors. In this study, we introduce a novel NO_2 breath sensor based on nitrogen-doped reduced graphene oxide-ZnO hollow spheres (N-rGO-ZnO) for the detection of NO_2 levels in human breath with high sensitivity and selectivity. The fabricated sensors are characterized in detail through different analytical techniques for their crystal structure, morphologies, chemical and physical properties, and the findings are consistent with each other. The proposed sensor shows a two-fold and five-fold increase in sensitivity compared to the sensors based on bare rGO-ZnO and ZnO hollow spheres, respectively. The proposed N-rGO-ZnO sensor exhibits excellent sensitivity as low as 100 ppb at 125 °C. An assessment of the efficacy of the proposed sensor for the detection of metabolic disorders through NO_2 sensing analysis in exhaled breath demonstrated that the N-rGO-ZnO hybrid nanocomposite-based e-nose sensor arrays produced distinct signals for healthy and simulated breaths. The signals did not overlap, indicating that healthy and unhealthy breaths could be accurately distinguished. Therefore, N-rGO-ZnO-based sensors represent a viable solution for screening metabolic disorders in patients and monitoring indoor NO_2 levels with ease. These non-invasive sensors offer a convenient and early detection method for metabolic disorders, enabling prompt treatment and improved patient outcomes.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2020R1A5A8018367, No. 2020R1I1A1A01073562).

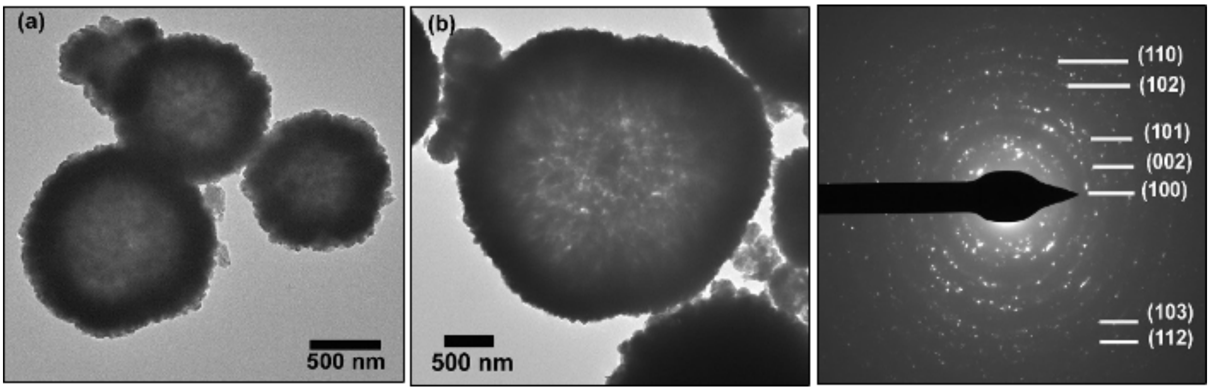

Fig. 1. Transmission electron micrographs and selected area electron diffraction analysis of the as-prepared N-rGO-ZnO hybrid nanocomposite.