AP22785922 “Development and production of heterostructured thin films with unique properties for highly effective detection of hazardous gases”

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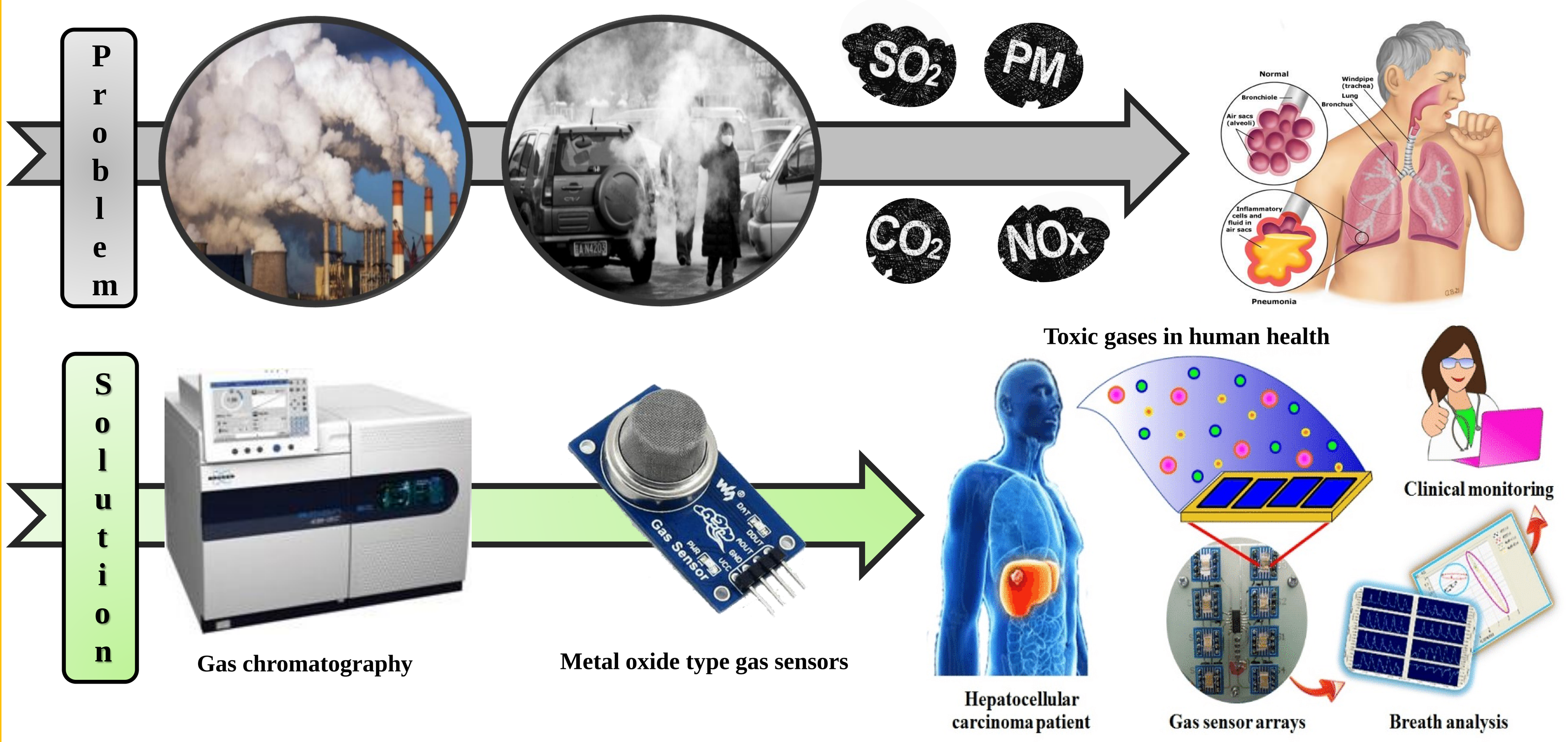
Graphical abstract



Introduction and aim

This ***project focuses*** on developing advanced gas sensors based on zinc oxide (ZnO) and its heterostructures to detect hazardous gases such as NO_x, CO_x, NH_3, H_2S, and SO_x. ZnO layers will be synthesized using methods like electrospinning, hydrothermal synthesis, and SILAR [1]. At the same time, substrates such as silicon and ITO will be utilized, along with gold-interdigitated electrodes (IDE) fabricated via magnetron deposition. The research aims to optimize the structural, electrical, and optical properties of ZnO and ZnO/MOS (metal oxide semiconductor) composites, improving their sensitivity, selectivity, and stability. Comprehensive characterization will analyze crystal structure, band gap, thickness, and conductivity. Gas sensitivity studies will evaluate operating temperatures and response times for detecting toxic compounds. Additionally, heterostructured ZnO/MOS composites with enhanced sensor properties will be developed to achieve high-performance detection. The project will culminate in the design and testing of an Arduino-based sensor platform for real-time gas monitoring, demonstrating its practical application in environmental safety.

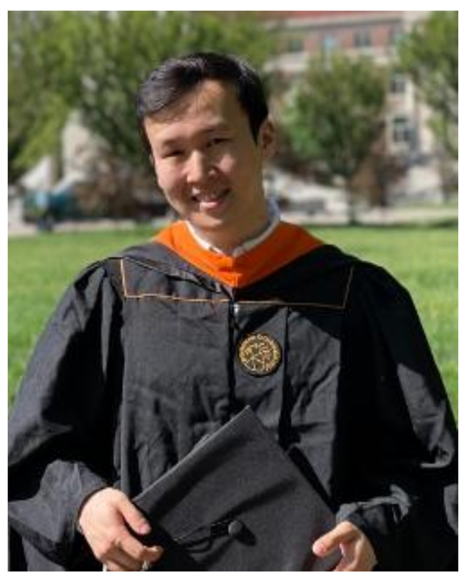
This work ***aims*** to create a working prototype of a reliable, selective, and highly sensitive gas sensor for monitoring air quality and detecting harmful gases in diverse industrial and environmental settings.

Project team and tasks

Dr. Baktiyar Soltabayev

Dr. Gani Yergaliuly

Prof. Almagul Mentbayeva



Mr Abylay Tangirbergen

Ms Diana Abdumutaliyeva

Ms student Aidarbek Nuftolla

•**Synthesis of Pure ZnO and IDE Customization**:
Techniques like electrospinning and hydrothermal methods will be employed to synthesize ZnO layers. Substrates such as silicon and ITO will be explored, and gold-interdigitated electrodes (IDE) will be developed using magnetron deposition. The goal is to optimize thin-layer structures for sensor applications.

•**Fabrication of ZnO Nanostructures and Gas Sensitivity Study**:
ZnO nanostructures will be synthesized using electrospinning, SILAR, and hydrothermal methods. Their gas-sensing performance will be evaluated for hazardous gases such as CO_x, NH_3, NO_x, H_2S, and SO_x. The focus will be on enhancing sensor sensitivity and selectivity.

•**Synthesis of ZnO/MOS Heterostructures**:
ZnO will be combined with metal oxide semiconductors (MOS) using chemical and SILAR methods. The resulting composites aim to improve selectivity, stability, and response times to toxic gases.

•**Comprehensive Property Analysis**:
The structural, electrical, and optical properties of the layers will be systematically analyzed. This includes studying thickness, crystal structure, electrical conductivity, and band gap, providing insights crucial for sensor optimization.

•**Sensitivity Testing of ZnO/MOS Heterostructures**:
Gas-sensing tests will be performed to determine optimal operating temperatures and response times for the synthesized heterostructures when exposed to gases like NO_x, H_2S, and CO_x. The goal is to develop a functional sensory prototype.

•**Development of Arduino-Based Sensors**:
The project will culminate in the integration and testing of the sensor on an Arduino platform. This will enable real-time gas detection, demonstrating the practical applicability of the developed sensors.

Modification approach of the project

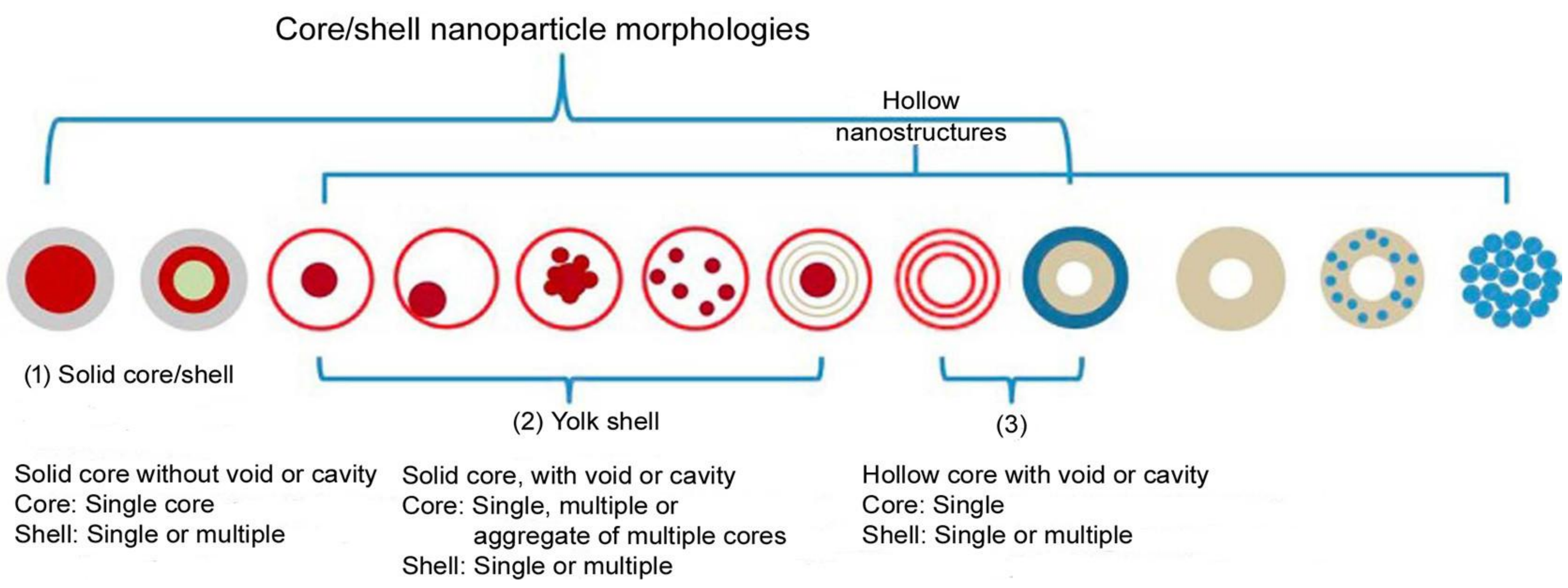
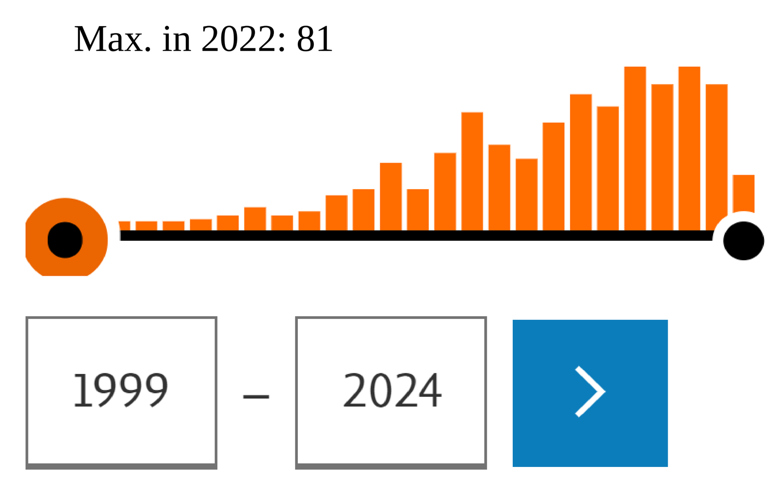


Figure 1.Schematic depiction of different kinds of Core/Shell nanoparticle morphologies where the core and shell are denoted in different colors [2]

Key words: **core-shell, gas sensor**

Scopus database



To date, research has primarily focused on enhancing the sensitivity of ZnO to various gases, with an emphasis on improving preparation methods and reducing operating temperatures. This work introduces a method for preparing ZnO@NiO core/shell nanofibers using a combined electrospinning/SILAR technique.

Conclusion

This approach results in a significantly larger surface area compared to plain ZnO/PVP fibers. The increased surface area enhances the sensitivity, selectivity, and response/recovery time of the nanofibers, while also allowing for a lower operating temperature.

Acknowledgments

This research has been funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. AP22785922, Development and production of heterostructured thin films with unique properties for highly effective detection of hazardous gases).

References

[1] Yergaliuly et al. Scientific Reports (2022)
[2] Dhiman S. et al. Journal of Agricultural and Food Chemistry (2021).