

# Executive Summary



NAVAKANTA BHAT

Dean, Division of Interdisciplinary Sciences  
Professor, Centre for Nano Science and Engineering  
Indian Institute of Science, Bengaluru-560012

1. Title of the Project: Nanostructured Semiconductor Gas Sensors
2. Date of Start of the Project: April, 2018
3. Aims and Objectives:
  - (i) Exploration of highly sensitive and selective semiconductor gas sensors using nanomaterials and nanostructured devices
  - (ii) Technology development for fully integrated and packaged gas sensors
  - (iii) Integration of gas sensors with signal conditioning electronics and calibration algorithms
  - (iv) Deployment for field trials and reliability assessment
  - (iv) Technology and product transfer to industry/start-up/user agencies
4. Significant achievements (not more than 500 words to include List of patents, publications, prototype, deployment etc)

We have been able to optimize the process flow for the wafer scale production of gas sensors, as a baseline platform technology with reasonable yield of about 50%. With this base line, any new processes, materials and device structures can be integrated to evaluate their performance as gas sensors. The size of the sensor chip either as a single sensing element or as an array of 4 elements is 1 mm<sup>2</sup> and on a 3 inch wafer, we have been able to produce more than 1,000 working gas sensor chips. A generalized signal conditioning interface electronics circuit with analog section and controller section was developed and prototyped. The analog section consists of transimpedance amplifier to convert sensor current into an equivalent voltage with appropriate gain. It also applies appropriate heater voltage to the sensor element. The controller section takes care of all other functionality including digital data conversion, user interface etc. A comprehensive strategy has been developed for packaging the gas sensors. Since the metal oxide based gas sensors are sensitive to ambient conditions, custom packaging is developed to account for this, by integrating humidity & temperature sensor. With an intent to deploy the sensors at SHAR, Sriharikota, for launch vehicle site hazardous gas leakage detection a comprehensive IP-64 compatible transmitter has been developed. The sensor and electronics assembly has been fully tested for reliability through accelerated burn-in tests. Appropriate algorithms are also being developed, based on field operating conditions to ensure for long term reliability of sensors. The complete technology is transferred to SCL, Chandigarh.

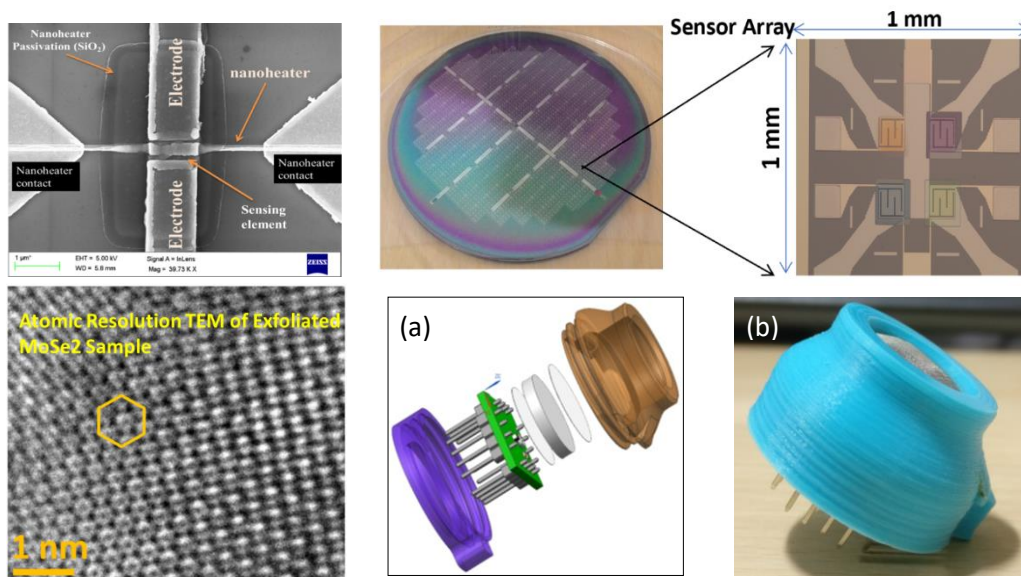
In parallel we have also explored new nano materials and device strategies for developing high performance gas sensors. In this context, core-shell metal-metal oxide structures have also been investigated. In addition, a variety of nanomaterials have been explored for highly sensitive and selective gas sensors.

Journal Publications:

1. Jha, et. al., IEEE Sensors Journal, 2021
2. Maria et. al., IEEE Sensors Journal 21 (9), 10420-10427, 2021
3. Jha, et. al., Nano Select, 2021
4. Ghosh et. al., Crystal Research and Technology 56 (1), 2000155, 2020
5. Sakhujia, et.al., ACS Applied Nano Materials 3 (11), 11160-11171, 2020
6. Jha, et.al., RSC Advances 10 (37), 21993-22001, 2020
7. RK Jha, et.al. *Nanoscale Advances*, 2020
8. Sakhujia, et.al., *ACS Applied Nano Materials*, 2020.
9. Jha, et. al., *Advanced Materials Interfaces*, 2020.
10. Raghavan, et.al., , *Materials Research Express*, 6 (12), 125907, 2019.
11. Prajapati, et.al., *Nanotechnology* 31 (2), 025301, 2019.
12. Jha, et.al., *IEEE Transactions on Nanotechnology*, 18, pp 932-939, 2019.
13. Sakhujia, et.al., *IEEE Sensors Journal*, 19 (24), pp 11767-11774, 2019
14. Jha, et.al., *IEEE Sensors Journal*, 19 (24), pp 11759-11766, 2019
15. Jha, et.al., *Sensors and Actuators B: Chemical*, 297, p 126687, 2019
16. Prajapati, et.al. *Crystal Research and Technology* 54 (4), 1800241, 2019
17. Benedict et.al, IEEE Sensors Journal, Vol: 19: 6 , March 15, pp 2023-30, 2019.
18. Benedict et.al., *Materials Research Bulletin*, Volume 112, pp 236-241, 2019

Conference Papers : 6, Book chapter : 1

- Patents : 1. PCT/IN2018/050646  
 2. PCT/IN2018/050670  
 3. US 17/398,169



19. Concluding remarks :

The project is progressing very well, with all projected milestones being met as per the timeline. Very significant research and technological milestones have been achieved.