ZnO/RGO Heterojunction based near Room temperature Alcohol Sensor with Improved Efficiency †

[1]S.Ghosal, [2]P. Bhattacharyya

[1]School of VLSI Technology, Indian Institute of Engineering Science and Technology, Shibpur- 711103, Howrah, India

[2]Nano-Thin films and Solid state Gas Sensor Devices Laboratory, Department of Electronics and Telecommunication Engineering, Indian Institute of Engineering Science and Technology (IIEST), Shibpur, Howrah, West Bengal, India-711103

Contact no: (+91) 9433428698; e-mail: sanghamitra.ju87@gmail.com

INTRODUCTION

Importance of 2D ZnO nanosheets

- Small thickness
- Extremely large surface

Provide strong coupling to different gas molecules

Importance of Reduced Graphene Oxide (RGO)

- Highly tunable Physical, chemical and Electronic property
- High Mobility Fast electron transport
- Abundant Defect states Facilitating gas interaction
- Low temperature based gas sensor

Motivation for developing 2D ZnO/RGO nanosheet structure

Present work is motivated to develop Hybrid device of RGO/ZnO nanosheets based near room temperature gas Sensor Device structure

EXPERIMENTAL

Material Preparation:

- FTO coated glass substrate
- ZnO nanosheet formation by Hydrothermal method with the electrolyte of 0.4 g of $Zn(NO_3)_2.4H_2O$ and 80 ml H_2O for 40 mins of continuous stirring
- 8 ml of 2M NaOH aqueous solution was introduced drop wise into the solution under stirring, resulting in a white aqueous solution, which was then transferred into Teflon-line stainless steel autoclave for 5-6 hours at 90 °C
- Annealed at 150°C for 1-30 hours
- RGO is prepared by 0.5 mg/ml aquous GO solution
- Electro-deposition for 100 minutes with 20 V bias
- Dried in N_2 jet and heated at 50°C in a temperature controlled (±1°C oven)

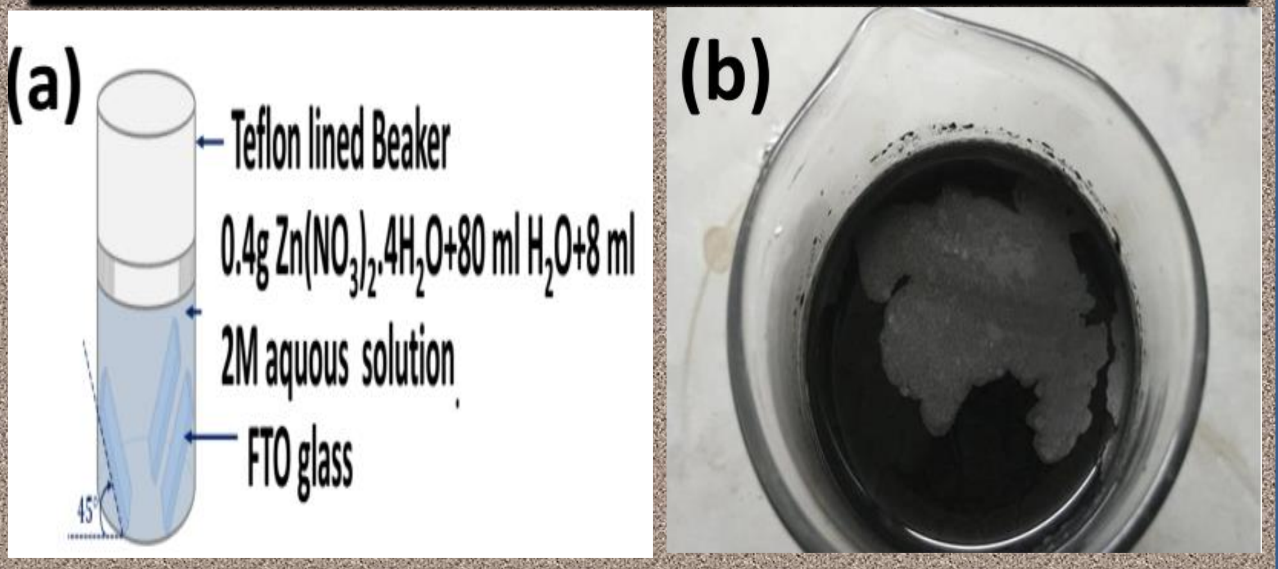

Fig. 1 (a-b): (a) Set up of ZnO-NS formation (b) RGO preparation in modified hummers method

DEVICE SCHEMATIC

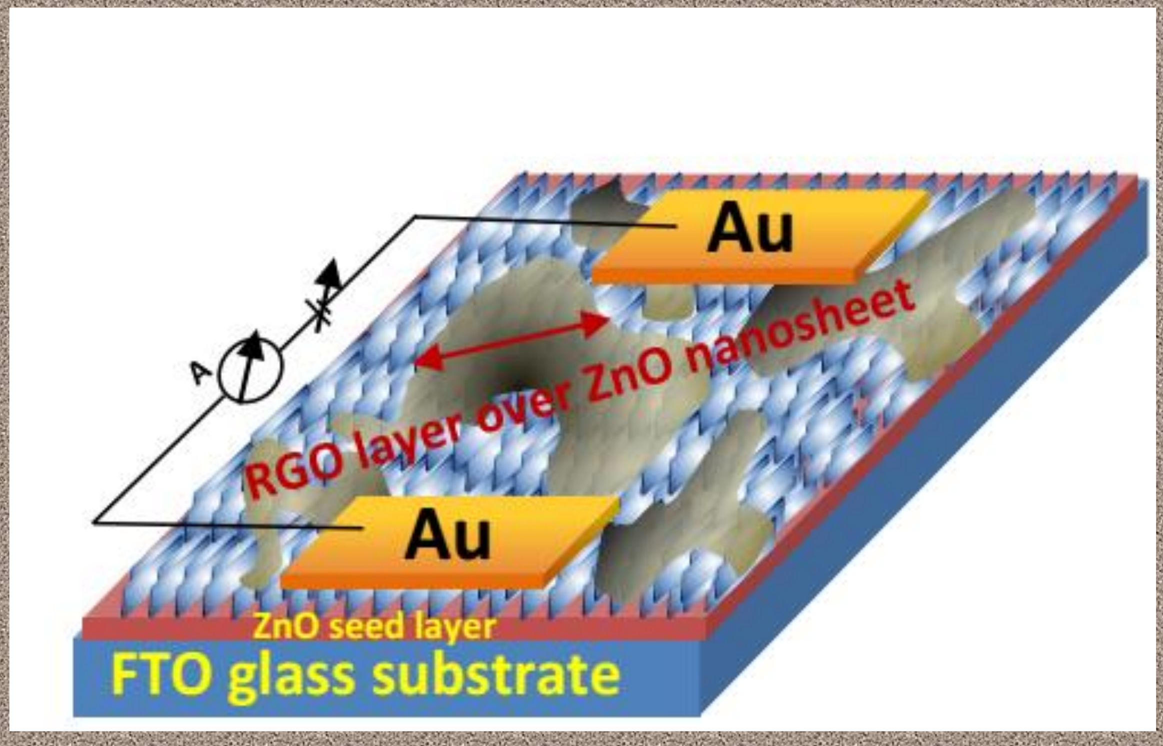

Fig. 2: Device schematic of ZnO-Ns/RGO hybrid structure

Two Gold (Au) electrodes (each having dimensions of 1.5 mm × 1.5 mm × 50 nm) were deposited by electron beam evaporation technique.

RESULTS

Material Characterizations

FESEM Analysis:

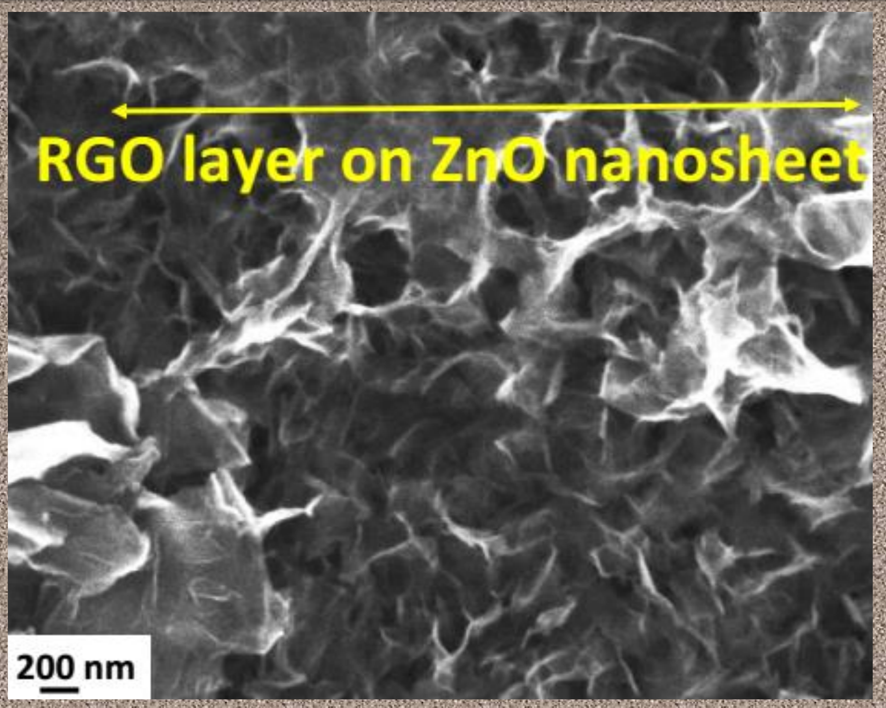

Fig.3: FESEM images (top view) of the hybrid structure

RAMAN Spectroscopy study:

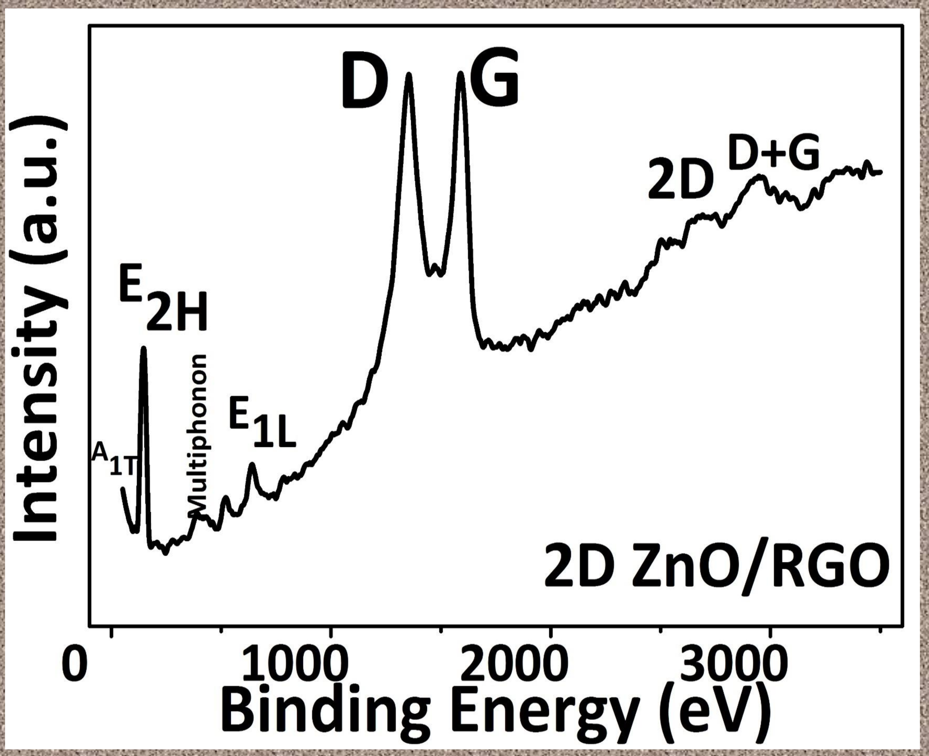

Fig.4: RAMAN shift of the hybrid structure

- D band is at 1355 cm^{-1}
- G band is at 1587 cm^{-1}
- 2D peak is at 2715 cm^{-1}
- E_{2H} band at 479 cm^{-1}, E_{1L} band at 628 cm^{-1}.

- non-polar optical phonon band in rGO-ZnO NSs confirms the wurtzite crystal phase of ZnO and also confirms that the presence of rGO does not alter the structural properties of the ZnO NSs.

XPS Analysis:

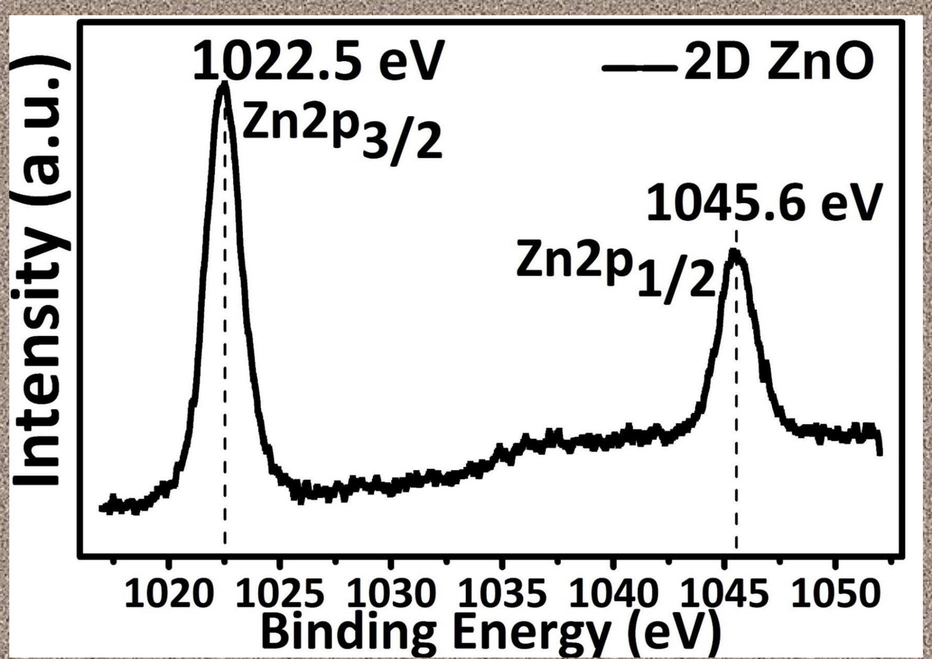

Fig.5: High resolution XPS spectra ($Zn2p_{3/2}$ and $Zn2p_{1/2}$) from 1020 eV – 1050 eV

Zn 2p core-level XPS spectrums of RGO-ZnO NSs shown, displays doublet spectral lines at binding energies at ~1022 eV (for $Zn2p_{3/2}$) and at ~1045 eV (for $Zn2p_{1/2}$) with a spin–orbit splitting (ΔE) of ~23.0 eV.

RESULTS

Sensing Characterizations

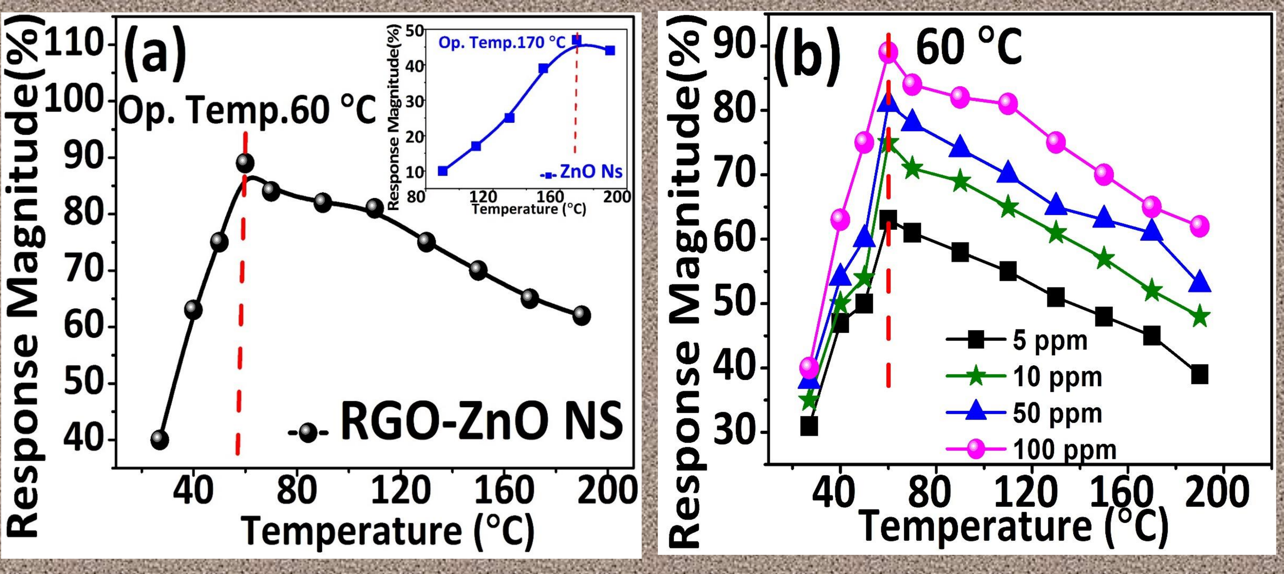

Fig.6 (a-b) : (a) Comparison of the optimum temperature of RGO-ZnO NS and ZnO NS at 100 ppm concentration; (b) Response magnitude variation for RGO-ZnO NS at optimum temperature 60 °C for 5, 10, 50 and 100 ppm of ethanol concentration

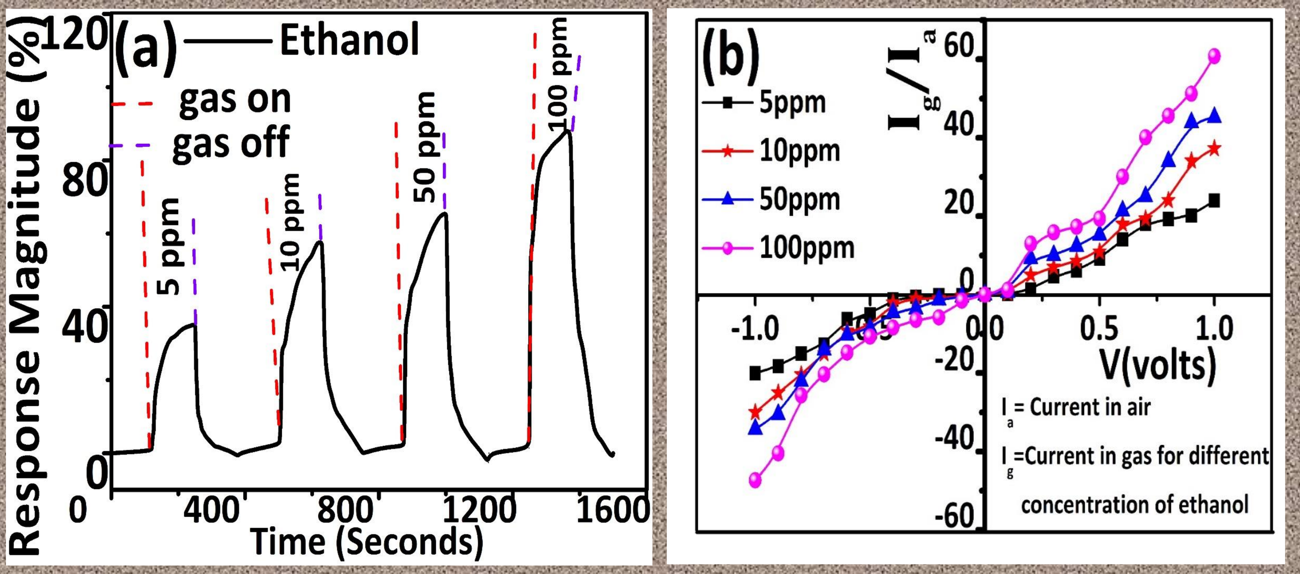

Fig.7 (a-b) : (a) Variation of response magnitude for different concentrations of ethanol at optimum temperature 60 °C (b) Ratio of current (I_g/I_a) in presence of different concentration of ethanol and air, as a function of voltages

SENSING MECHANISM

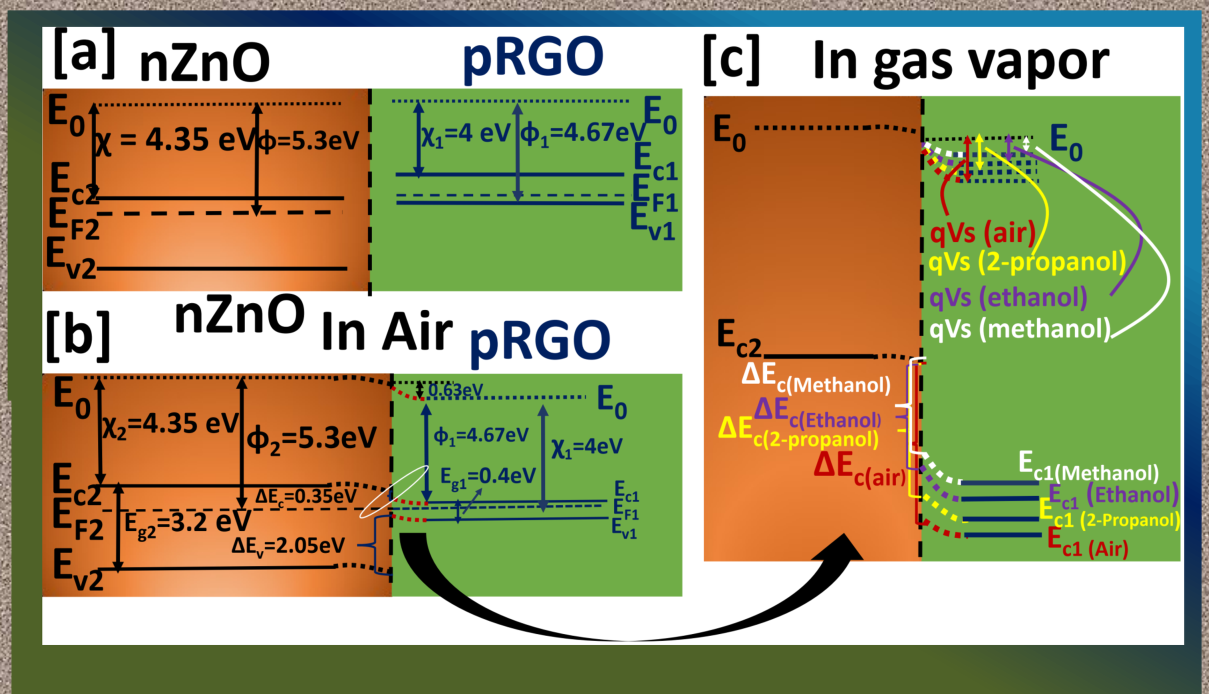

Fig.8: Energy Band Diagram of the ZnO/RGO hybrid structure

Acknowledgement:

Sanghamitra Ghosal gratefully acknowledges Visvesvaraya scheme, MeitY, for her Ph.D.

CONCLUSIONS

The RGO/ZnO-Ns hybrid structure offered potential gas sensing characteristics due to Hybridization of two sensing element viz. ZnO nanosheet and RGO in synergistic fashion.

Paved the path for future gas sensor device with:

- Very fast response time
- High sensitivity
- Low temperature detection capability
- Low ppm detection
- High response magnitude
- ZnO NSs radially offers higher amount of gas adsorption/desorption sites (large surface to volume ratio).
- RGO increases the carrier transport from the gas-interaction sites, improves the response magnitude than pristine nanosheet structure at low temperature
- RGO also acts as a highly efficient (due to high mobility) conducting support between the nanosheets: Improved response time

REFERENCES

1. S. Basu et al. "Recent developments on graphene and graphene oxide based solid state gas sensors," *Sens. Actuators, B*, **2012**, vol.173, pp.1–21.
2. X. Wang et al. "Highly sensitive, temperature-dependent gas sensor based on hierarchical ZnO nanorod arrays" *J. Mater. Chem. C,* **2015**, vol. 3, no. 93, pp. 11397-11405.
3. G. Thien et al. "Highly exposed {001} facets of titanium dioxide modified with reduced graphene oxide for dopamine sensing, **2014,** "*Nature Sci. Reports*, vol. 4, pp.1-8.
4. K. Dutta et al. "A highly sensitive BTX sensor based on electrochemically derived wall connected TiO2 nanotubes," Appl. Surf. Sci., **2015** vol. 354, pp. 353-361.
5. K. Dutta et al. "Ti/TiO2Nanotube Array/Ti Capacitive Device for Non-polar Aromatic Hydrocarbon Detection", IEEE Trans. Dev.& Mat. Rel. **2016** vol. 16, no. 2, pp. 235-242.
6. A. Hazra et al. "Low temperature methanol sensing by p-type nano-titania: Correlation with defects states and Schottky barrier model", IEEE Trans. Nano. **2014** vol. 14, no. 1, pp. 187-195.

I3S – 2021, 8th International Symposium on Sensor Science(17th – 18th May 2021)