Innovative strategy to recognize the diabetic state of people: metal oxide nanorods as ultrasensitive exhaled gas sensor

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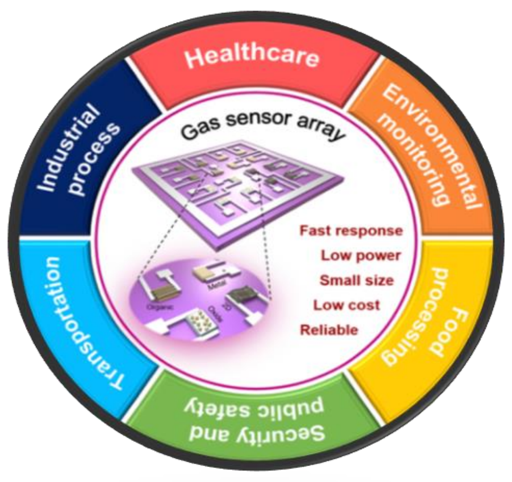
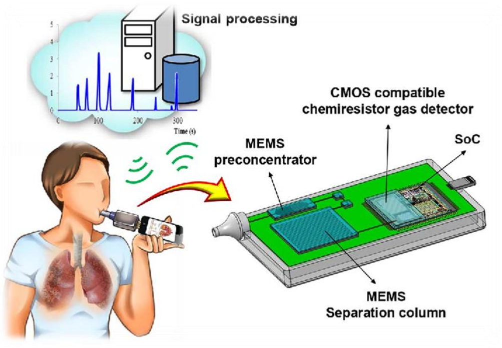
INTRODUCTION

In recent years, the development of gas monitoring devices/sensors are critical for environmental protection and for humans promptly. Due to their good characteristics as fast response, low cost, and small size gas sensors have become more prevalent in different fields from healthcare industries to food processing [1].

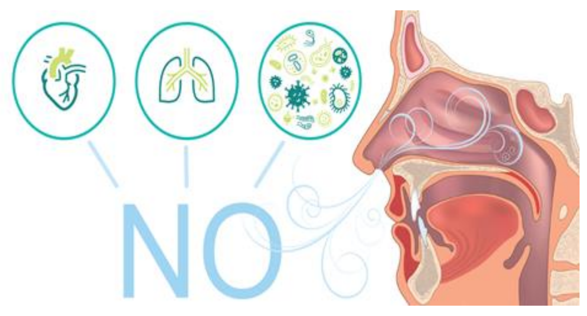




In breath sensing, metal oxide semiconductor (MOS) sensors are commonly utilized. MOS sensors are one of the finest alternatives for breath analysis because of its:

- compact size,
- ease of operation,
- low cost,
- and minimal maintenance [2].

However, conventional gas sensors with a single metal oxide layer, detect a shift in bulk resistance in response to gas contact, resulting in limited gas sensitivity and selectivity. For increasing gas sensitivity and selectivity, forming a p-n junction with MOS-based p-type and n-type electrodes is the best option

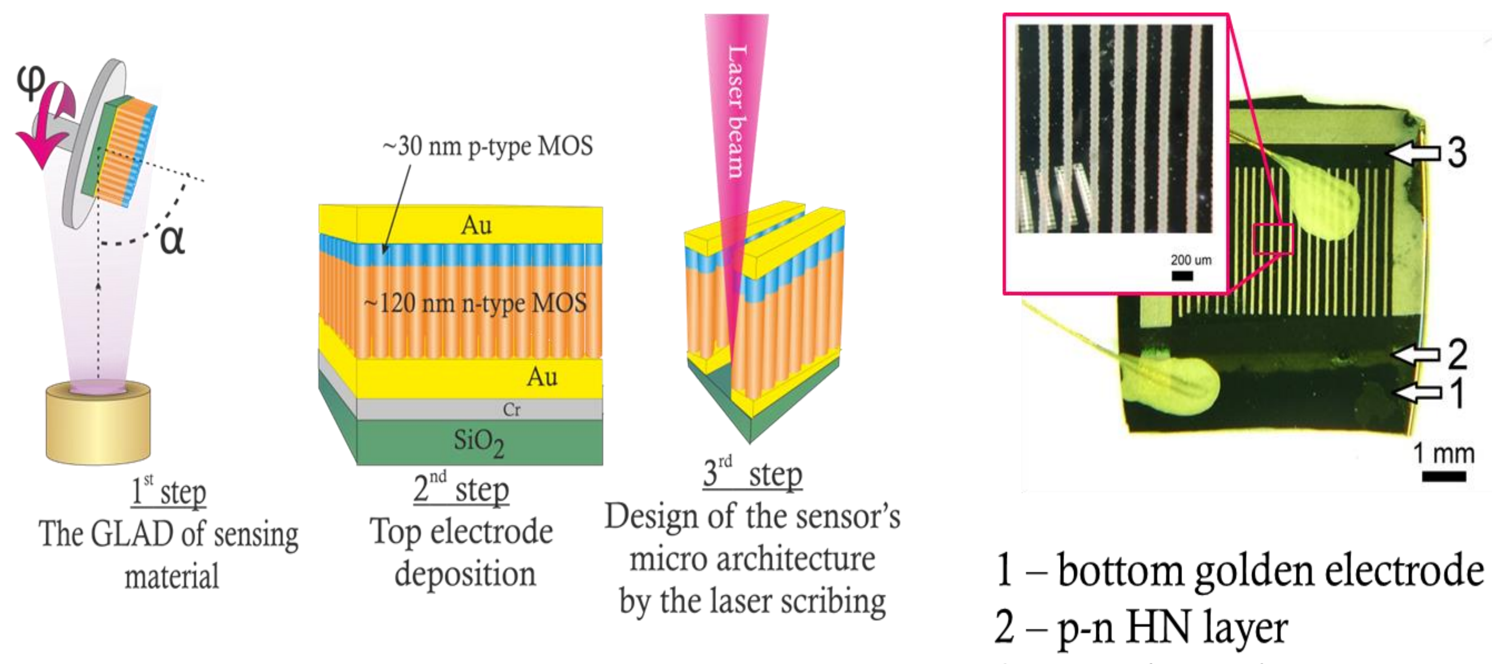


This research purpose to investigate gas sensor based on p-n heterostructures of MOS (TiO/CuO) with nanoscale architecture which is ultrasensitive for VOCs and work at low temperature (room temperature)

EXPERIMENTAL PART

The p-n heterostructured (p-n HS) gas sensors were obtain by glancing angle deposition of metal target at reactive magnetron sputtering. The nanorods-like structures deposited in the sequentially or another words in same process.

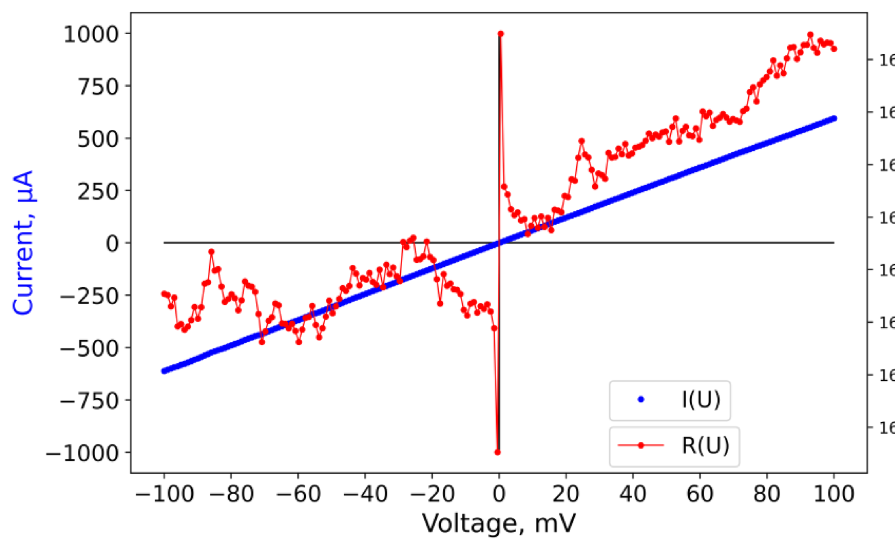
The magnetron sputtering was carried out in the 20% oxygen/argon atmosphere. The width of the TiO_2 layer was ~ 120 nm, while the width of CuO layer was 30 nm. The smaller width of the CuO layer is derived by idea of matching of the depletion layer width with the CuO film one.

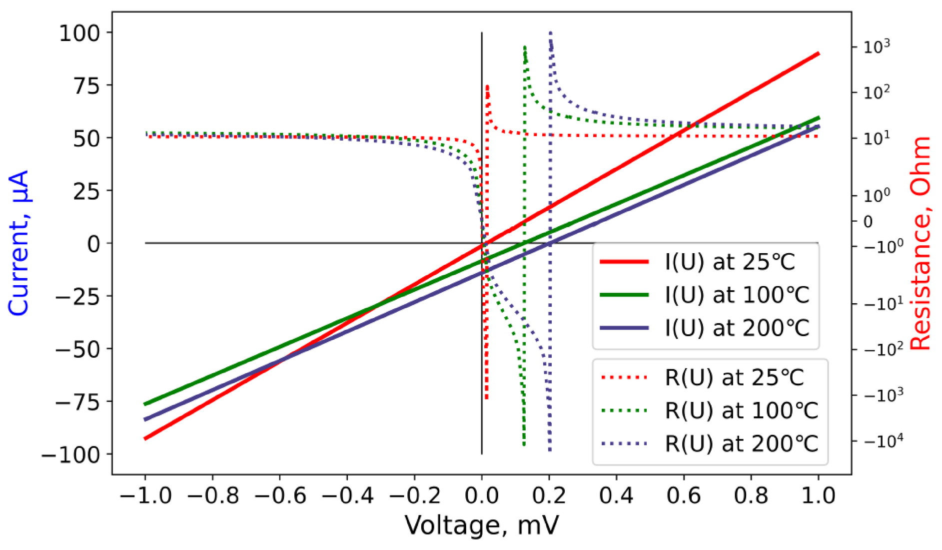


1 – bottom golden electrode
2 – p-n HN layer
3 – top electrode

Formation of gas sensor consists of general 3 steps: 1st The GLAD of p-n HS; 2nd deposition of top electrode; 3rd step – laser scribing for the increasing active surface area. According to the developed method more than 20 samples of p-n HS samples were obtained.

RESULTS AND DISCUSSION

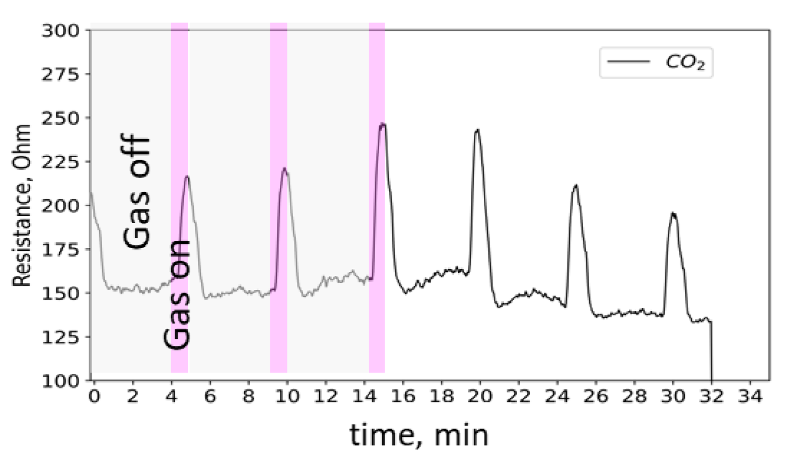


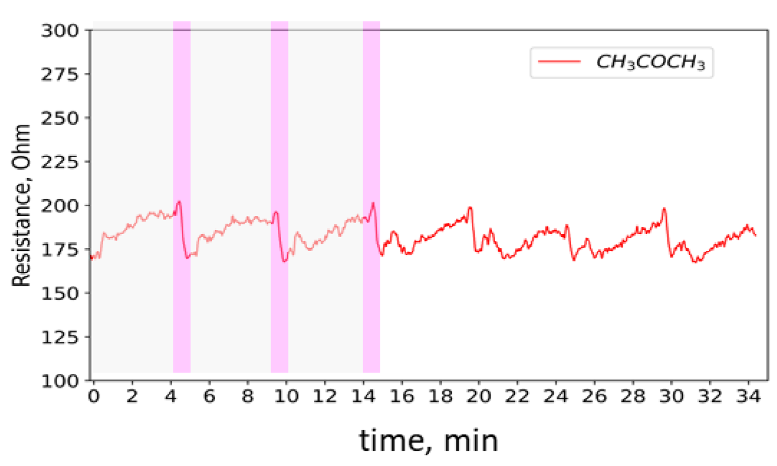


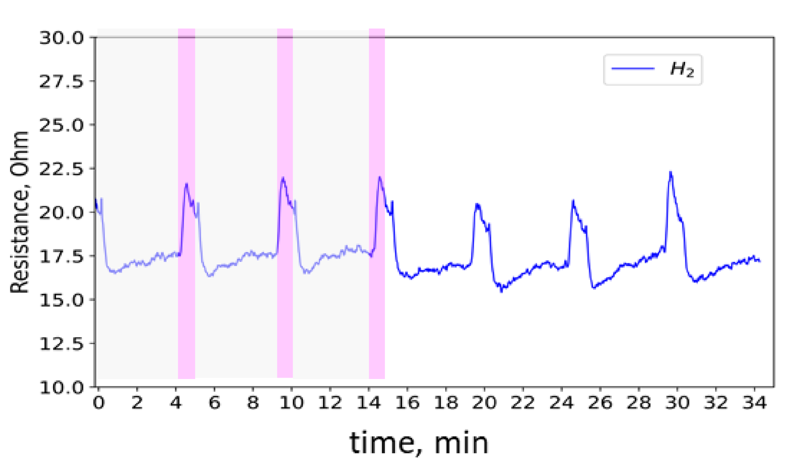
The dependence of current over the voltages belongs Ohmic Law and shows linear independence. Sharp changes of resistance at low voltages might indicate the electromotive force of the heterostructures between the layers p-n heterostructures. This electromotive force increases with the temperature

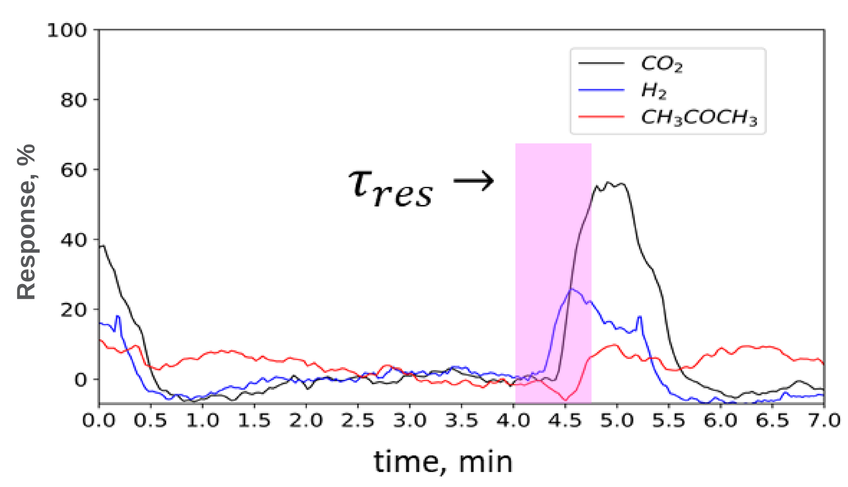
Dynamic gas response characteristics

Gas type	Response time, s	Recovery time, s
CO_2	~48 s	~40 s
Acetone	~51 s	~205 s
H_2	~33 s	~150 s









The measurements were conducted at RT and 10 ppm concentration of target gases was applied. The gas response was calculated by the equation 1.

$$N_{res} = |R_a - R_g| / R_a \times 100\% \qquad (1)$$

The sensitivity test was conducted for reducing and oxidizing gases (CO2, H2, Acetone). The highest response was recorded for the CO2 gas ~ 60 %. The lowest response was observed for the acetone, ~10%. The fastest response time was recorded for the H2, highest recovery time observed for carbon dioxide.

It is well known that the oxidizing CO_2 gas contributes holes after reacting with adsorbed oxygen, whereas the reducing H_2 gas catches holes after reacting with adsorbed oxygen, suggesting that the TiO_2/CuO HS n-type sensing capabilities. Despite the fact that the concentration of CO_2 gas is the same with H_2 gas, the current through the sensor is remarkably lowered by 10 times after CO_2 exposure. This suggests that under CO_2, the electron concentration in the n-TiO_2 NHs dramatically decreases.

CONCLUSION

The experimental results show possibility to develop RT gas sensors based on p-n nanointerfaces. The dynamic gas response parameters can be accepted as good. Despite good sensitivity and dynamic parameters the sensors don't show stable results. The further investigation to be continued to provide theoretical explanation of conductivity mechanisms at low potentials. The crystallographic characterization and phase verification problems should be solved.

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