SHB: Type I (EXP): Personalized Asthma Monitor Detecting Nitric Oxide in Breath

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Abstract

Nitric oxide is a well-established biomarker for airway disease monitoring and there are set guidelines regarding the concentration of this gaseous biomarker in human exhale for various medical conditions. Based on these guidelines, our project aims at developing handheld and inexpensive single breath exhale monitors (NO breathalyzers) that will assist with early asthma diagnosis and easy monitoring of the disease. The approach followed is based on selective chemosensing using resistive sensors with polymorphic metal oxide sensing elements. We have succeeded thus far in processing single crystal nanowires of the β-MoO_3 and γ-WO_3 polymorphs, both materials being NO selective sensing probes. Recent progress is shown in sensing trace NO amounts in breath simulated environments and also in developing numerical devices for breath collection, monitoring and display of the NO concentration in a single exhale.

BACKGROUND

- A chemo-resistive gas sensor is a device which reacts with its surrounding gas and converts this reaction into a change of its electrical resistance in a distinctive manner
- Polymorph control in nanostructured metal oxides enables them to become gas-selective chemo-resistors
- Our nanostructured sensors have specific affinity to the targeted gaseous biomarker

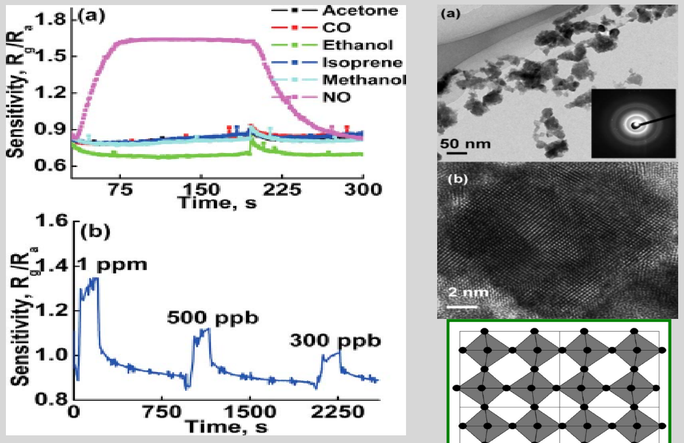
Crystallo- Chemical Approach to Gas – Metal Oxide Interactions

Group A :oxides with the rutile structure (tetragonal),: SnO_2, CrO_2, IrO_2, β-MnO_2	**Reducing Gases: Type I** gases :CO and Volatile Organic Compounds
Group B :oxides with the ReO3 structure (cubic/perovskite); WO_3, β-MoO_3	**Type II** gases include NH_3 and amines
Group C of oxides with a weakly bonded layered structure: α-MoO_3 , h-WO_3	**Oxidizing gases: Type III** refers to O_2, NO/NO_2

Table1: Selectivity of certain oxide structural groups to classes of gases [1-2]

Results from earlier studies by the PI

NO detecting selective nanosensor based on nanostructured thin films



From Gouma et al, Appl. Phys. Lett. 93, 244102, 2008

Figure 1: Earlier sensing results for NO sensing by thin films of γ-WO_3 [3]

Patents granted:

- US/Patent No **7,017,389** issued on 3/28/2006, "Sensors Including Metal Oxides Selective for Specific Gases and Methods for Preparing Same", by **P.I. Gouma**
- US/Patent No **7,981,215** issued on July 19, 2011, "Electrospun Single Crystal MoO_3 nanowires for bio-chem sensing probes", by **P.I. Gouma**, A. S. Haynes, and K. Kalyanasundaram

Detecting NO biomarkers

Disease Marker	Typical Concentration In human breath	Our NO detecting Sensors
Asthma	Nasal Few ppm	• β-phase MoO_3 • Sol-gel • Nanowires
Oxidative stress Lung diseases	Breath Low ppb	• γ-phase WO_3 • Sol-gel • Nanowires
See ATS Clinical Practice Guidelines [4]		

Table 2: NO is a biomarker for airway diseases in a given concentration range

- Key biomarker: NO in breath
- Measuring FENO measures airway inflammation [4]
- NO is detectable in exhaled air in significant amounts: from 0.2–1 ppm in the upper respiratory tract; and 1–30 ppm at the nasal level
- Both the American Thoracic Society (ATS) and the European Respiratory Society (ERS) have published guidelines for the measurement of FENO]

MATERIALS & METHODS

Novel Sensing Materials

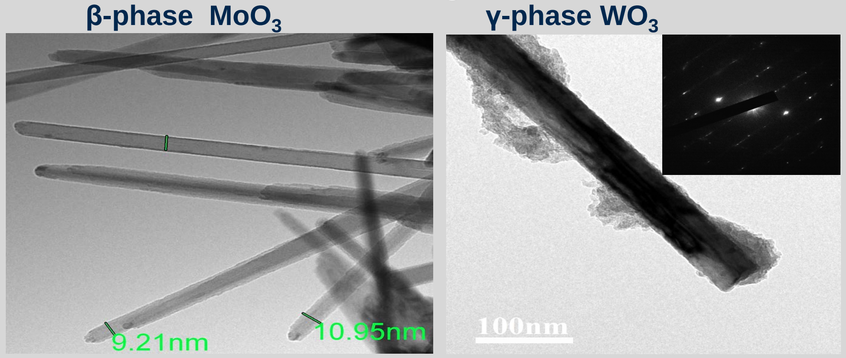
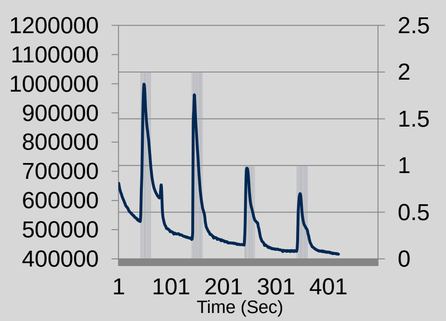


Figure 2: Single crystal nanowires of the ReO_3 structural group that are expected to detect NO with high specificity:(Left) MoO_3 and (Right) WO_3

Novel Sensor Design and Testing



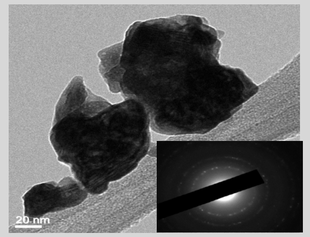


Figure 3: (Left)Sensing data for γ-WO3 nanosensors tested for 1ppm and 2ppm NO gas; (Right): Morphology of the grain structure of the sensing elements.

Binary (On/Off) handheld breath analyzer

HANDHELD DEVICE PROTOTYPE

Our innovation lies with empowering the individual to acquire affordable, non-invasive medical diagnostic tools for home use

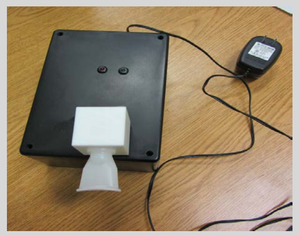


Figure 4: Binary breath analyzer [6]

DIMENSIONS

- Teflon chamber of binary prototype: 15cm (L) x 7.5cm (Wseparates sensor from electronics and the environment.
- Channel with mouthpiece controls breath flow to sensor

From P. I. Gouma et al, IEEE Sensors, 10 (1), pp. 49-53, 2010

Numerical Breath Analyzer

Figure 5: (Left)Numerical breath analyzer; (Right) Sensor chip that is the brain of the numerical analyzer [7].

SPECIFICATIONS

- Single breath, portable, handheld, numerical
- 3 sensor device, battery operated; 1 year lifetime
- One sensor is for CO_2 detection; used for standardization/calibration purposes
- Stand alone device- Instant digital readout of gas concentration; no need for computer or pattern recognition software

[from Gouma et al, J. Breath Res. 5 , 2011

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