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**Multifunctional Nanowire/Film Composite-based
Bimodular Sensors for In-situ, Real Time High
Temperature Gas Detection**

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@ DOE/NETL Cross-Cutting Research Program
Project Review Meeting



OUTLINE

Project Overview

Year-2 Project Accomplishments

---- nanowire arrays based sensors

---- nanofibrous films based sensors

---- Bimodular sensor fabrication and initial testing

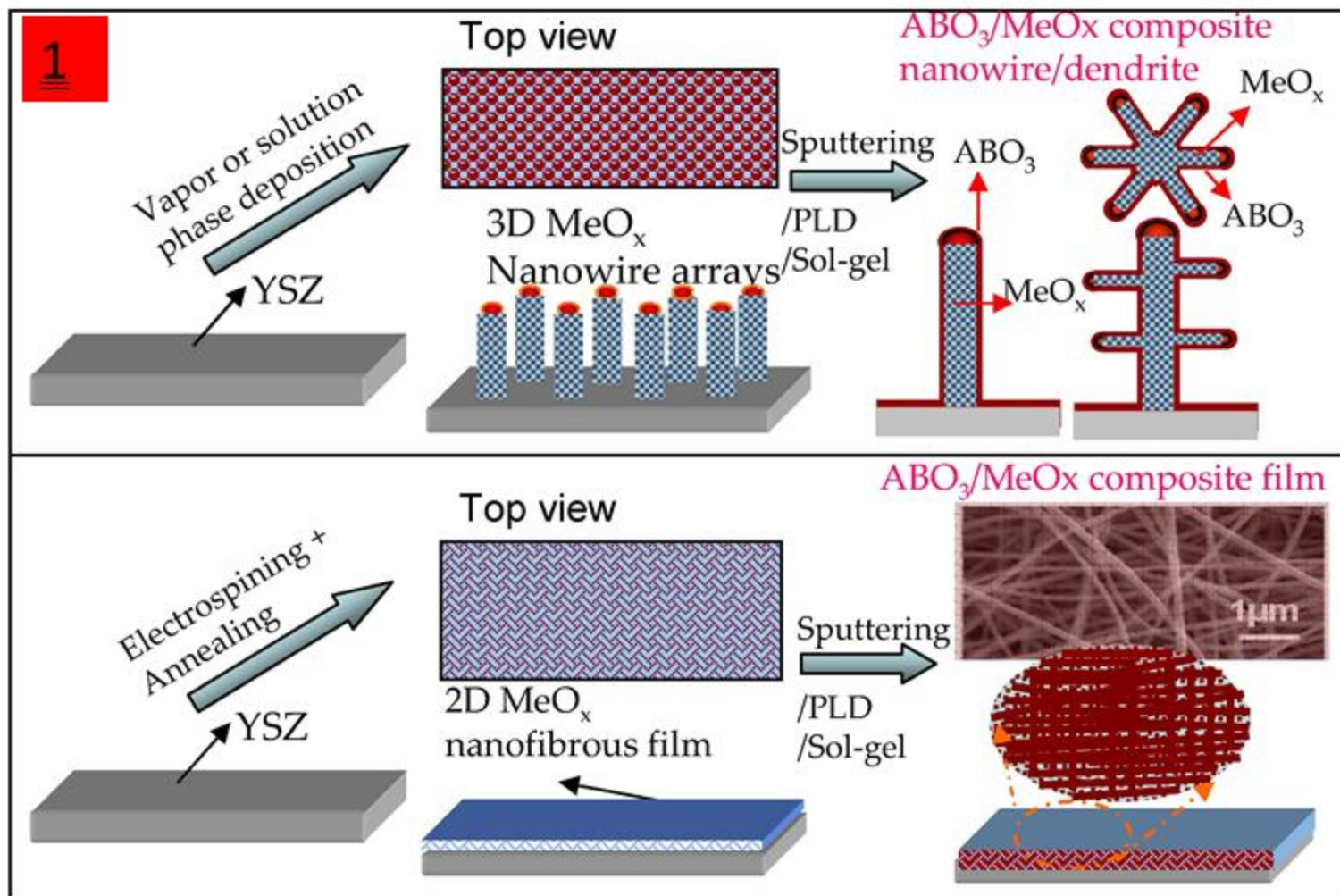
Progress Chart and Deliverables

Project Overview

- Date: 10/01/2009 –9/31/2012
- Project Objective:
 - To develop a unique class of multifunctional metal oxide/perovskite based composite nanosensors for industrial and combustion gas detection at high temperature (700 °C-1300 °C).

Task #1

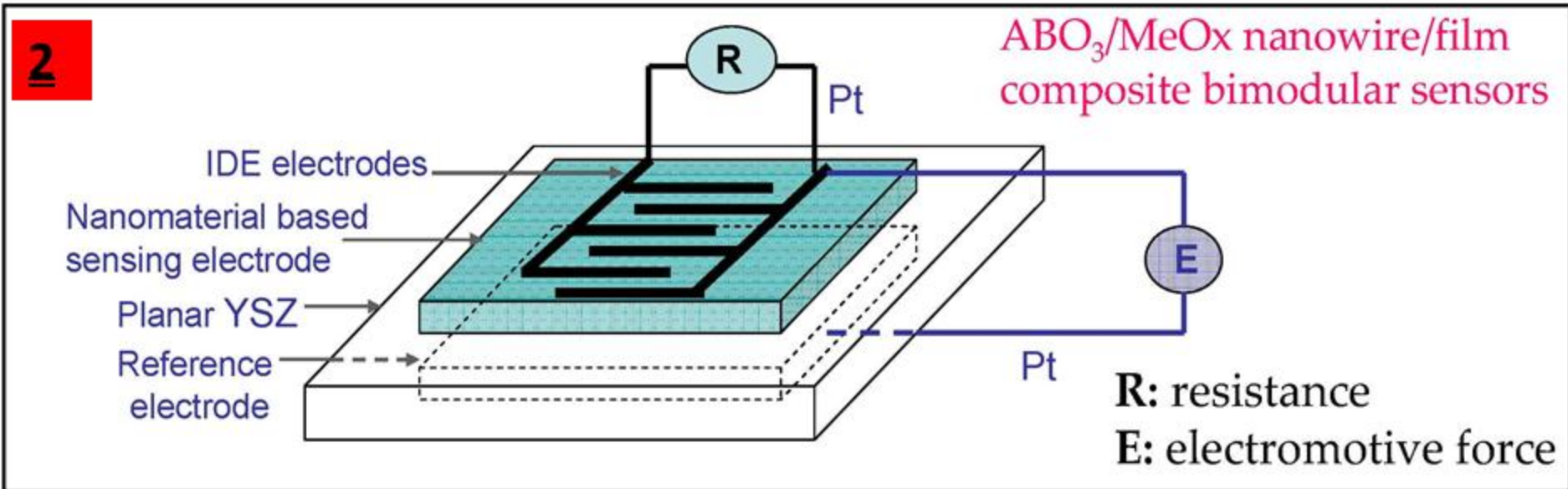
Nanowire/Nanofilm Composites



Materials Advantages: 1) Ultrahigh surface area; 2) High thermal stability; 3) Strong adherence; 4) Low cost; 5) High tailoring ability

Task #2

In-situ and Real-time Biomodular Gas Sensors

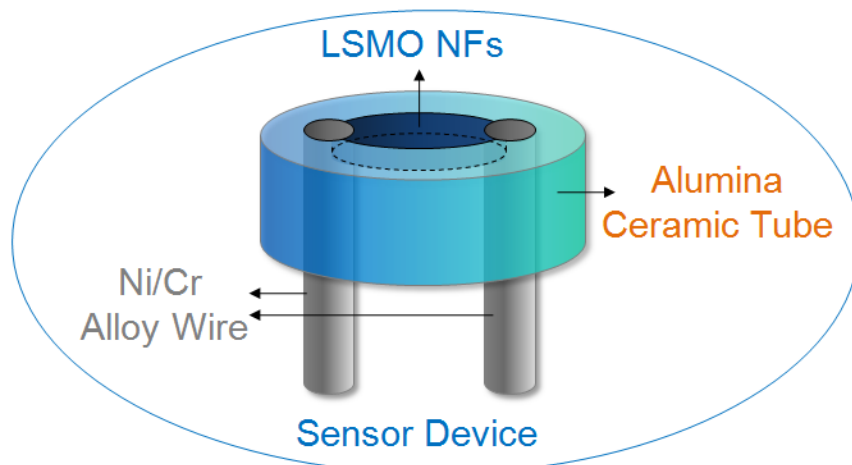


Sensors Advantages: 1) Ultrahigh surface area induce high sensitivity; 2) Catalytic filtering induced selectivity enhancement; 3) High temperature thermal stability; 4) Low cost; 5) High tailoring ability; 6) Two nearly independent measurement data sets (bi-modular)

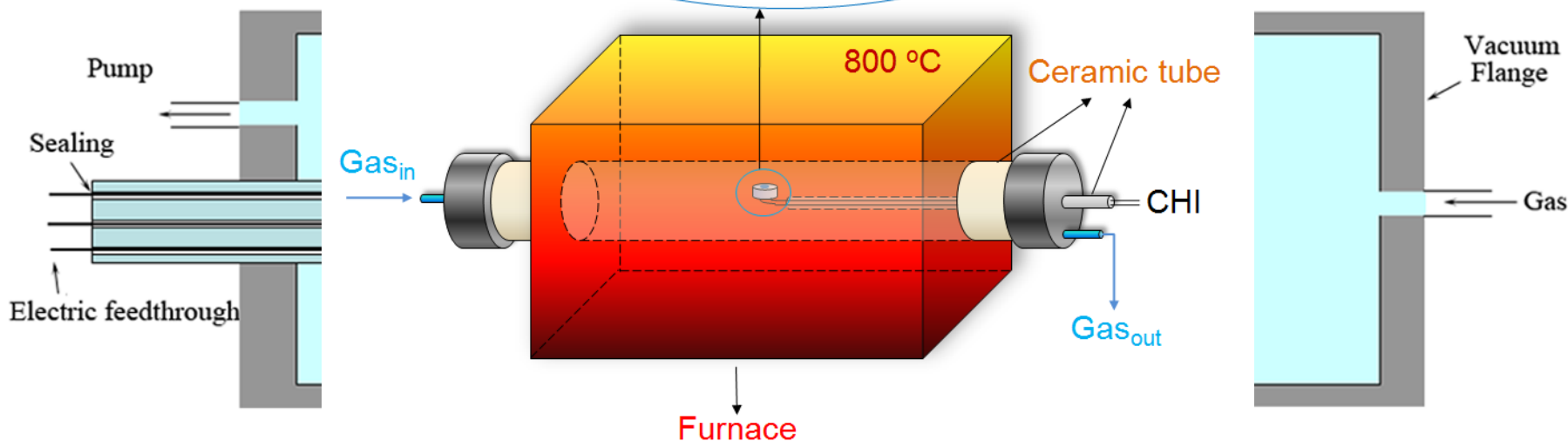
Year-2 Accomplishments

- ✓ Nanowire arrays Sensors (ZnO, ZnO/LSCO)
- ✓ Nanofibrous films Sensors (LSMO, CeO₂, Pt/CeO₂)
- ✓ Initial biomodular sensor fabrication and testing on nanowires/films (NiO/Pt, ZnO/Pt)

Electrodes and high temperature sensor testing setup



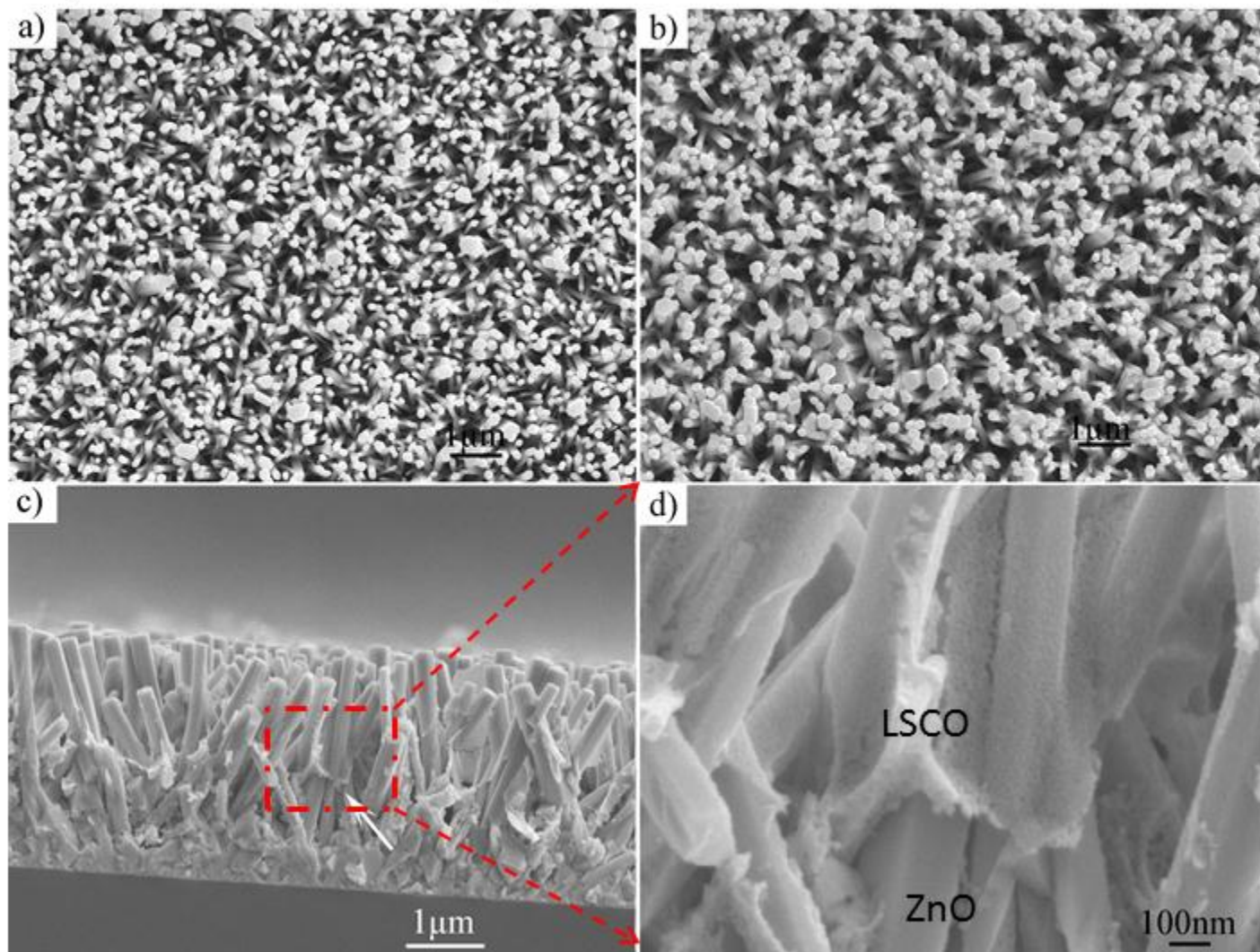
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Liu et al., 2012, RSC Advances, In press.

Gao et al., 2012, In preparation.

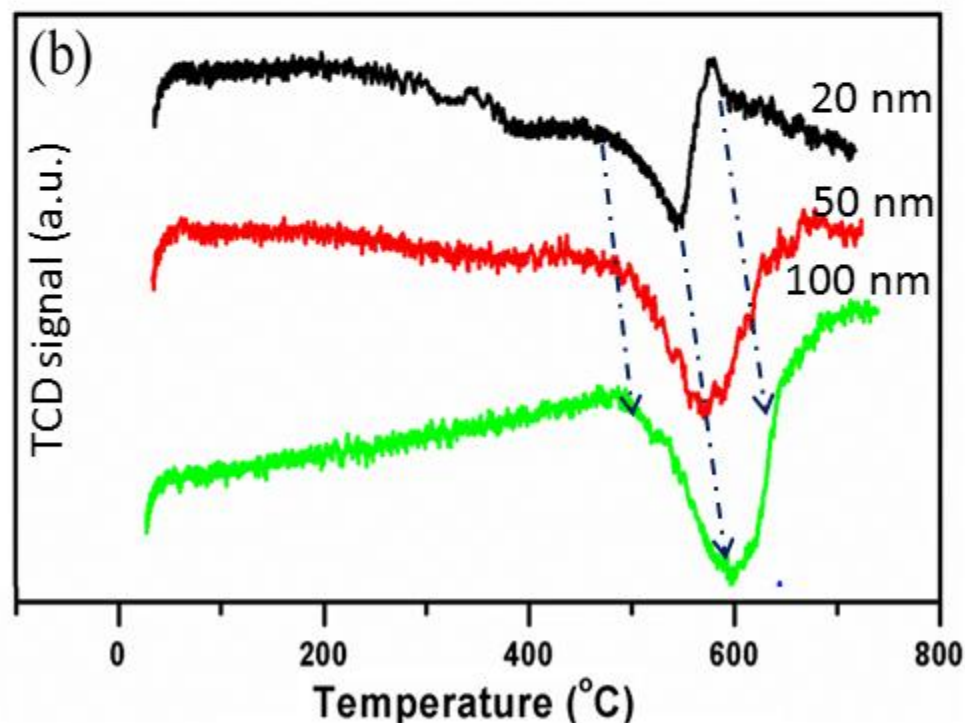
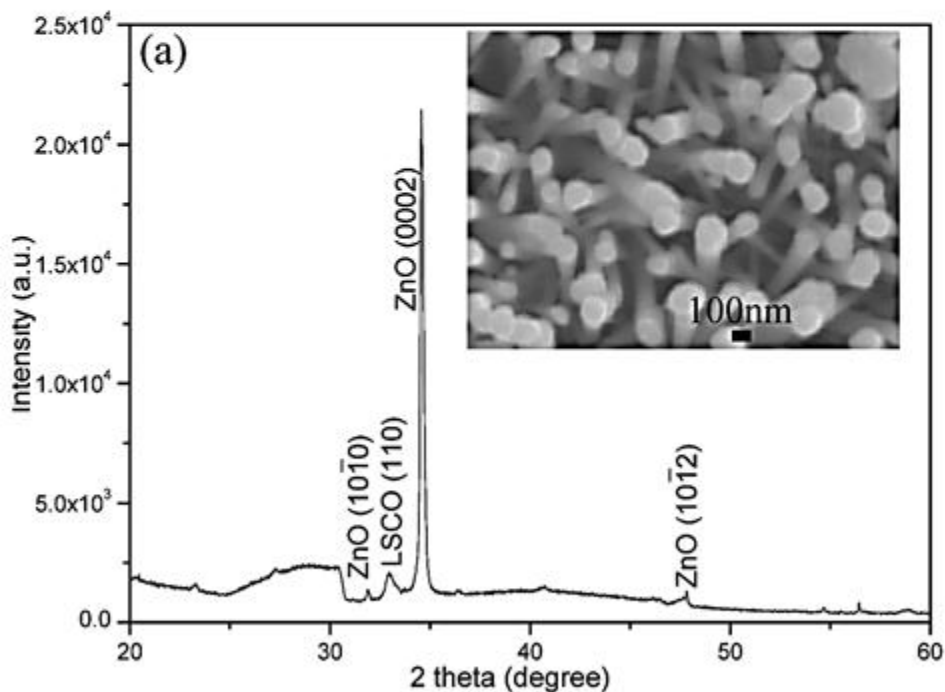
ZnO/LSCO composite nanowire arrays



Gao et al., 2010, *J. Phys. D.*, (fast track communication)

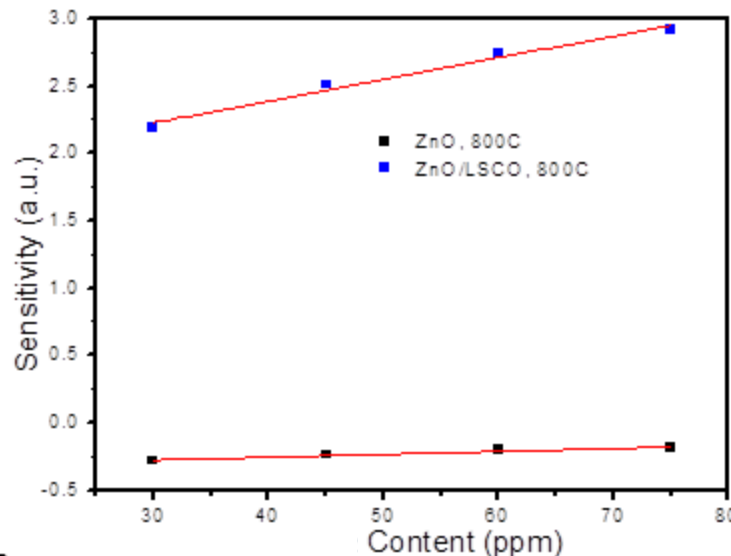
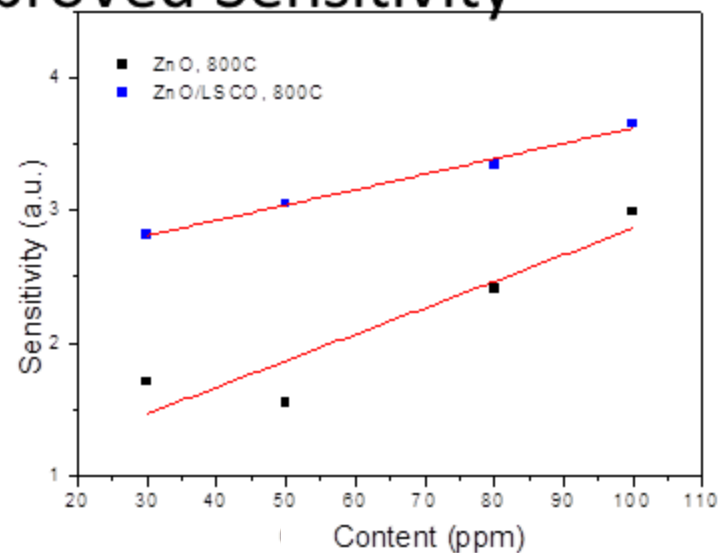
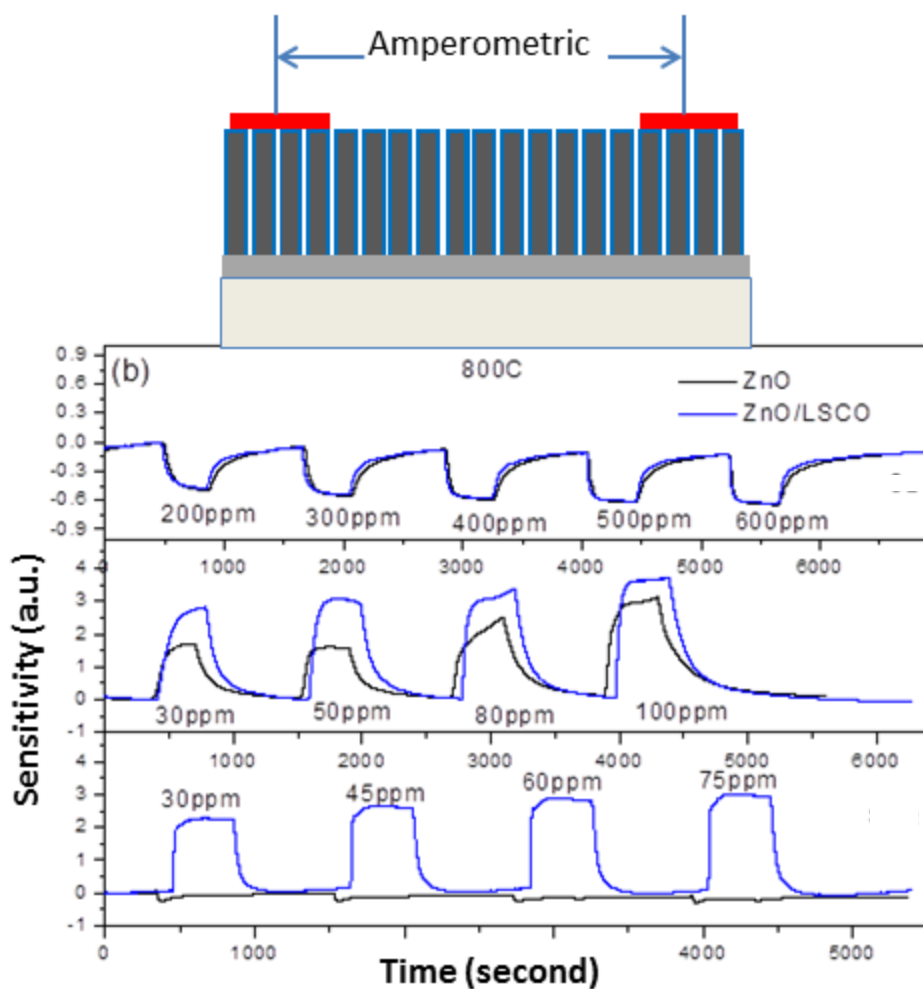
Thermal stability under reducing atmosphere

- Improved thermal stability



ZnO and ZnO/LSCO nanowire Sensors

- Excellent reversibility and Improved Sensitivity

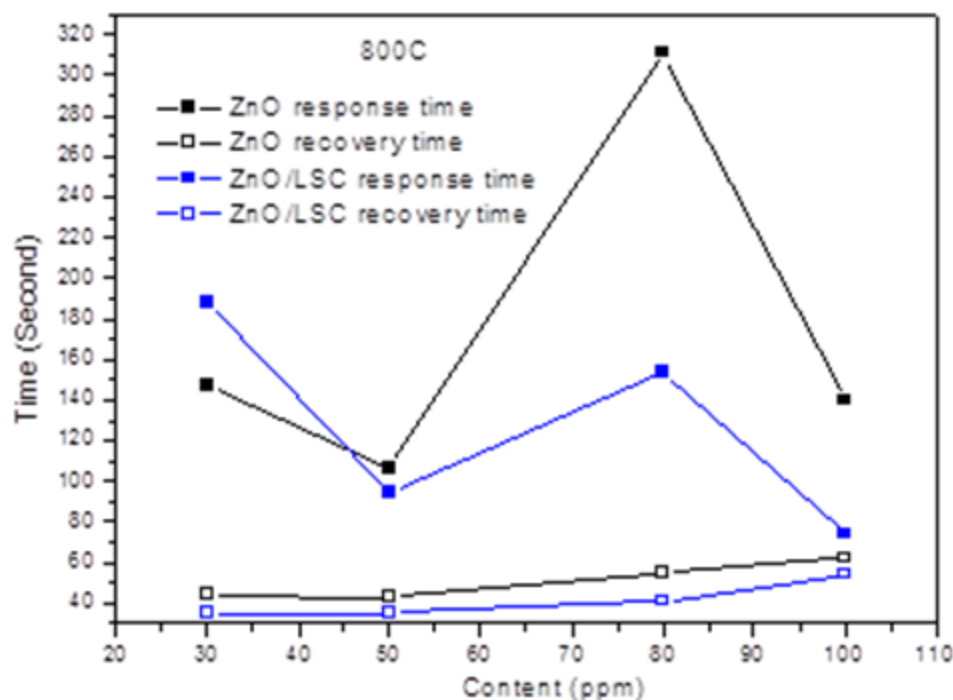
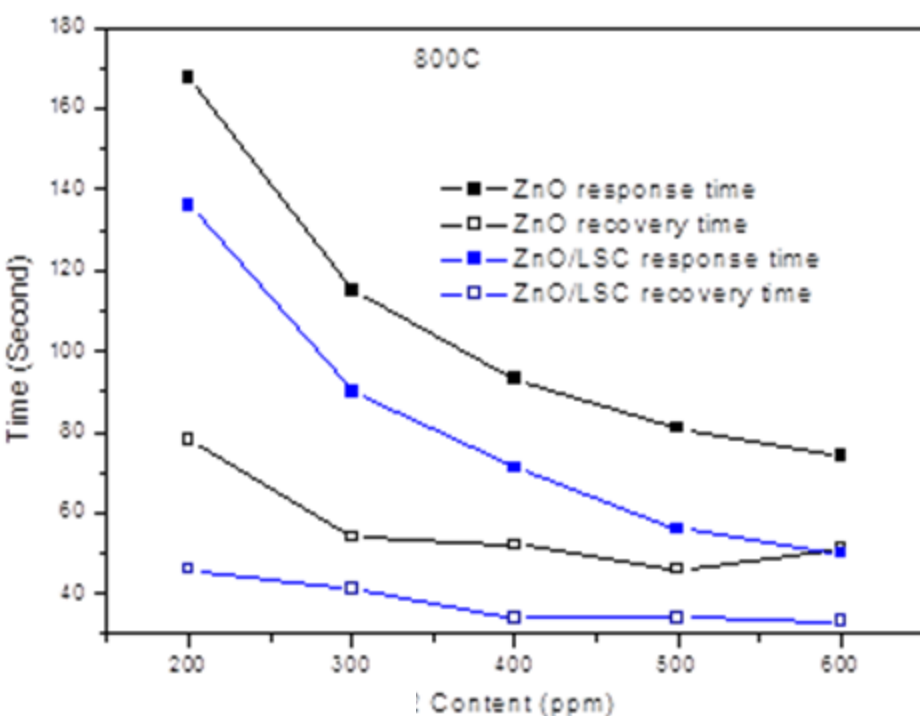


Gao et al., 2012, In preparation.

Gao et al., 2012, Patent Application, In preparation.

ZnO and ZnO/LSCO nanowire sensors

- Improved response and recovery (O_2 , CO, SO_x , NO_x , H_2)



Response and recovery: tens of seconds faster in ZnO/LSCO than ZnO.

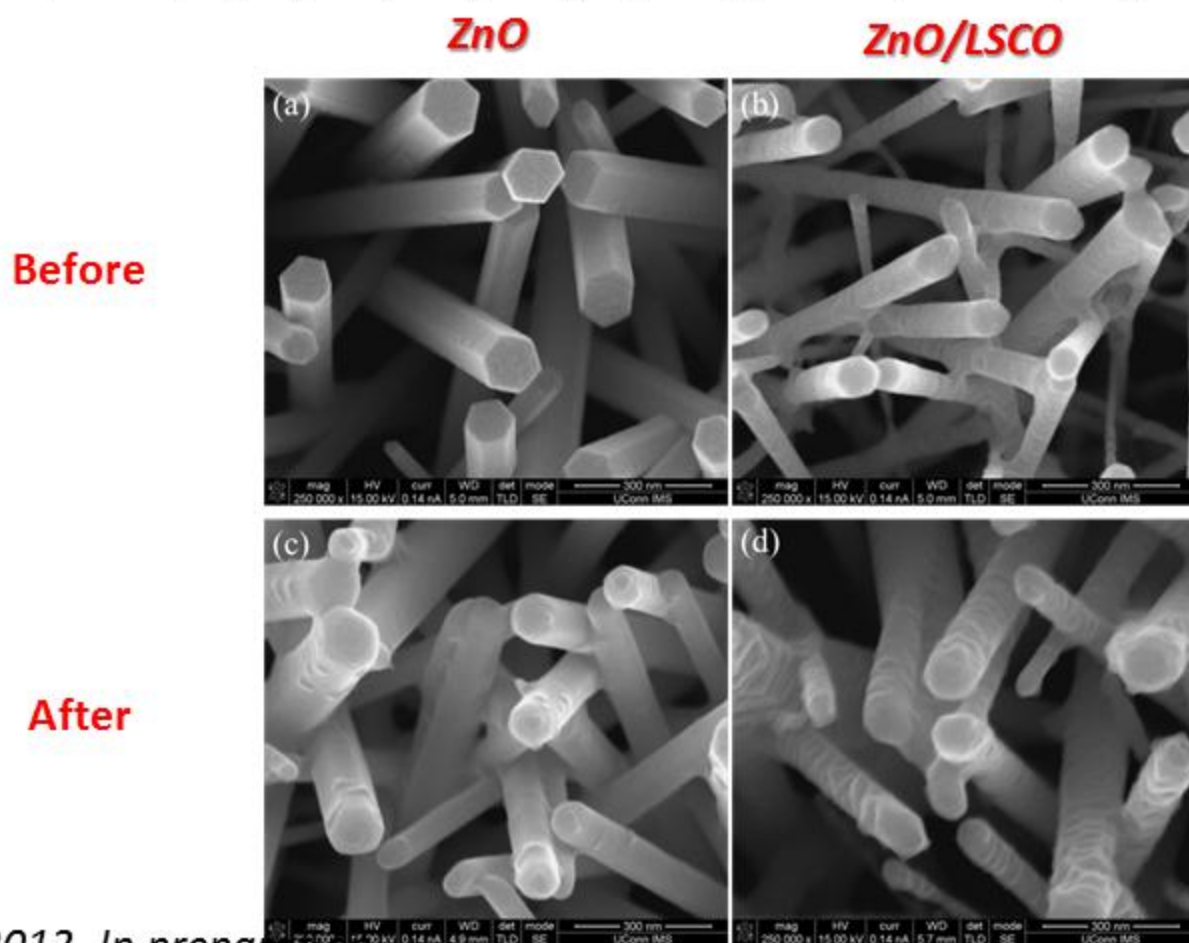
Gao et al., 2012, In preparation.

Gao et al., 2012, Patent Application, In preparation.

ZnO/LSCO nanowire sensors:

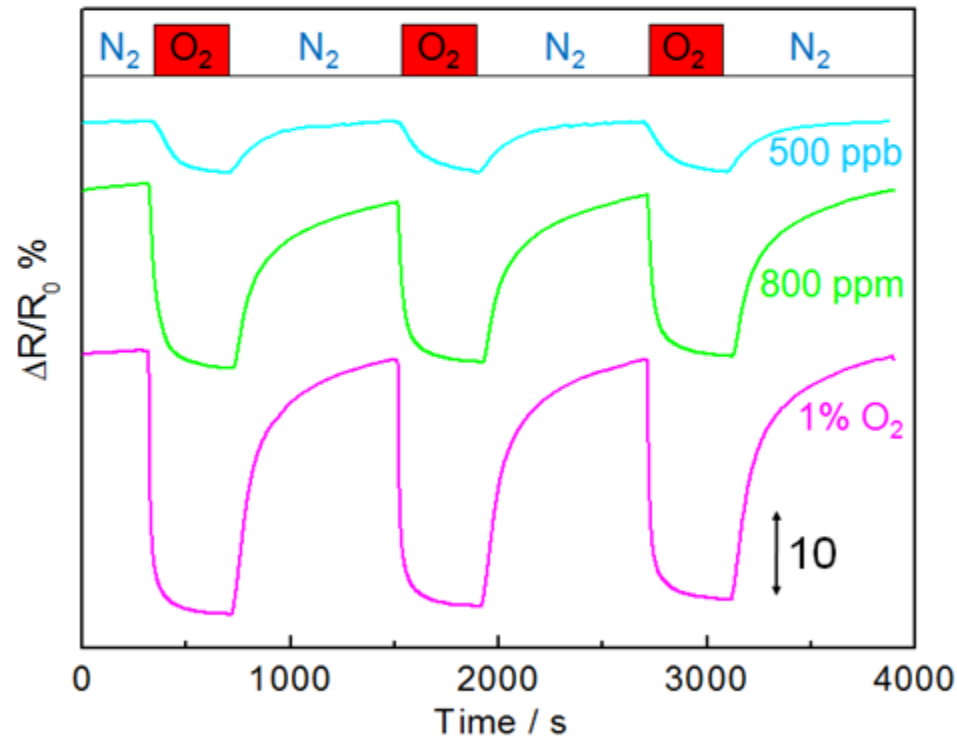
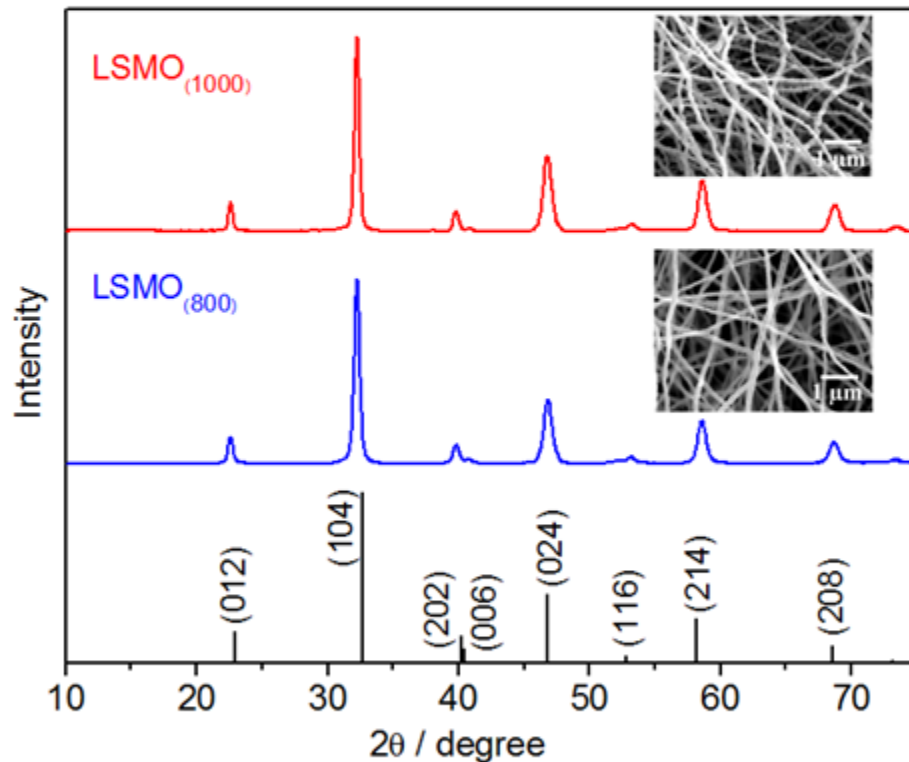
Thermal stability

- Early ambient results: ZnO/LSCO showed great structure and chemical stability up to 1000 °C for 24 hours.
- Before and after 800 °C gas sensor test for a few days under multiple gaseous atmosphere (O_2 , N_2 , CO , CO_2 , SO_x , H_2 , NO_x) with cyclic ramping and cooling history.



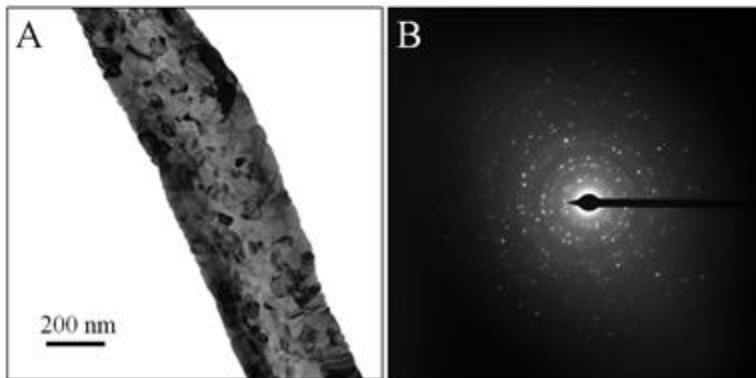
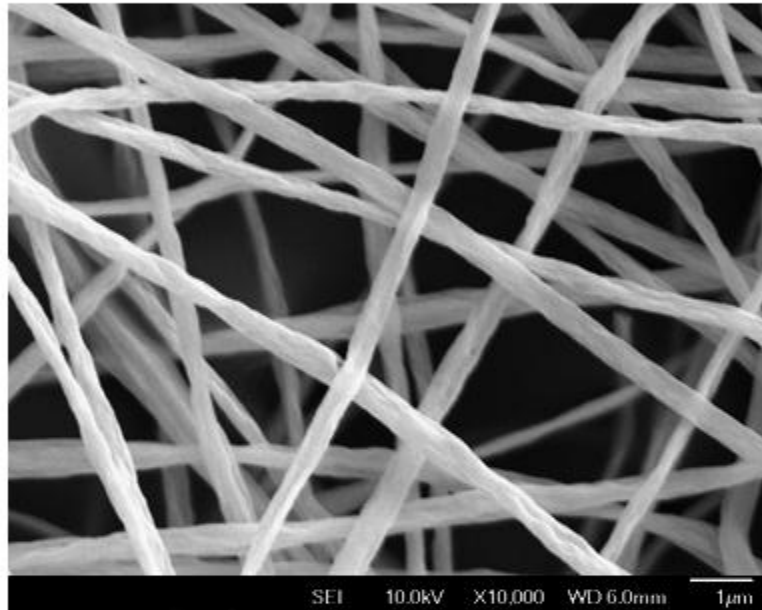
(La,Sr)MnO₃ nanofibers sensors

- High temperature stability and sensing performance

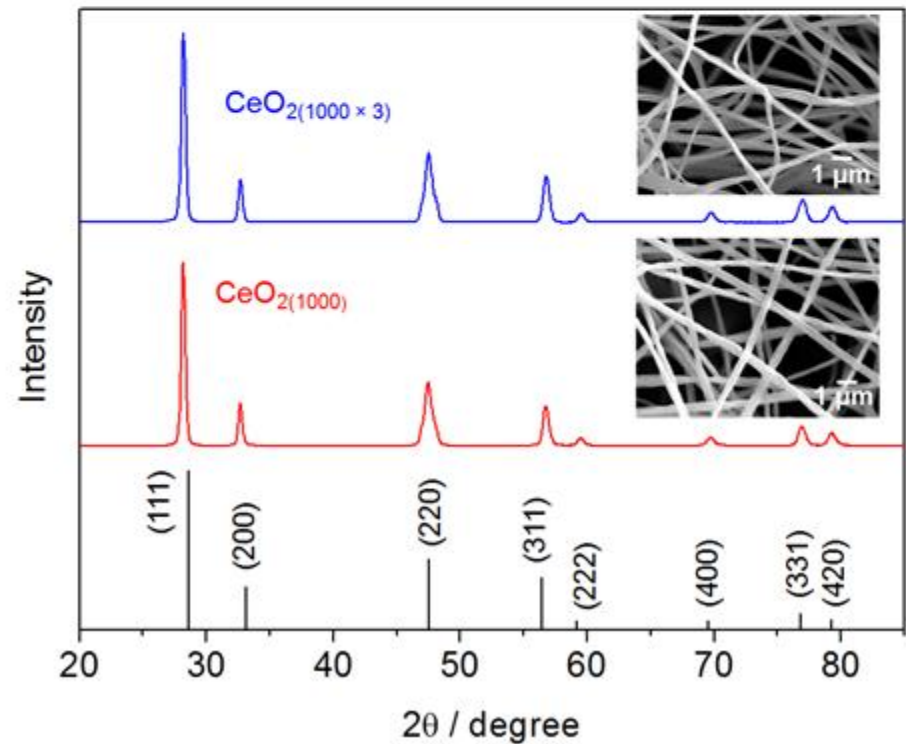


CeO₂ nanofibers sensors

– Characterization



- CeO₂₍₁₀₀₀₎ NFs: electrospinning
calcined at 1000 °C for 3 h
- CeO_{2(1000×3)} NFs: heating/cooling cycle
1000°C – T_{room} (3 times)

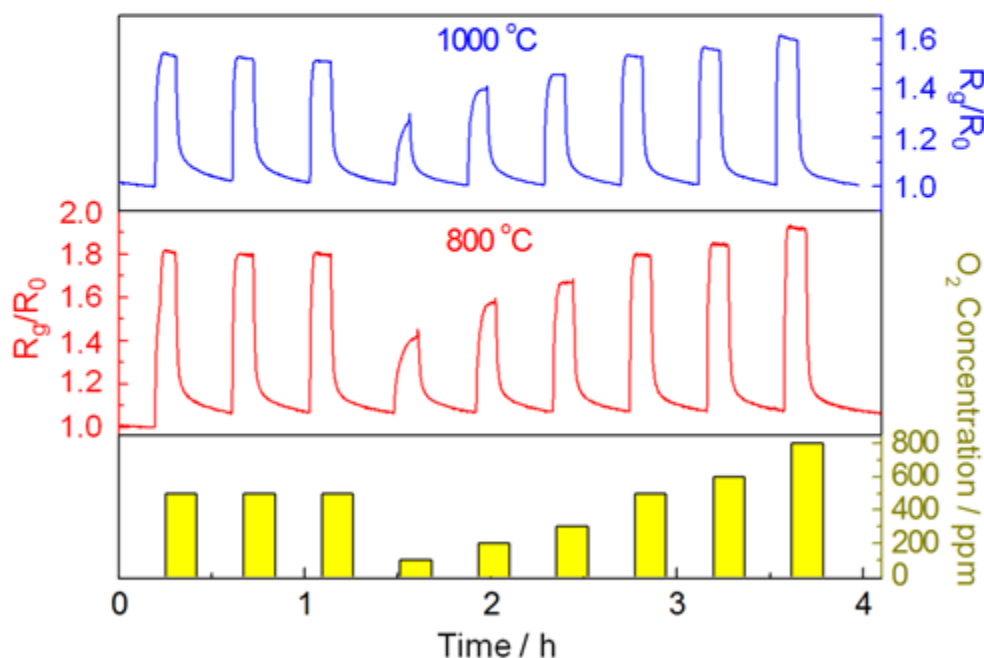


CeO₂ nanofibers sensors

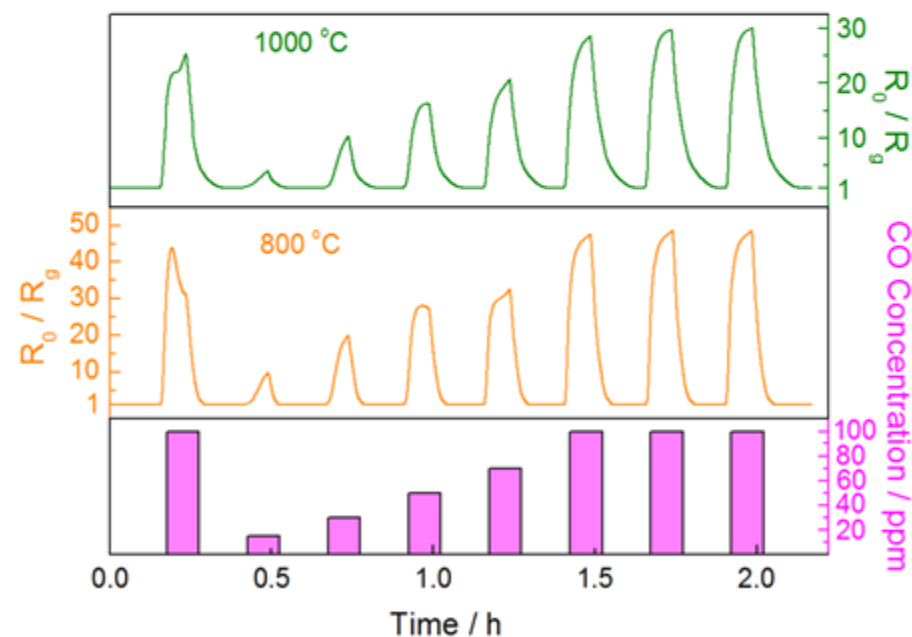
– O₂ & CO sensing

- 800 °C and 1000 °C

• O₂



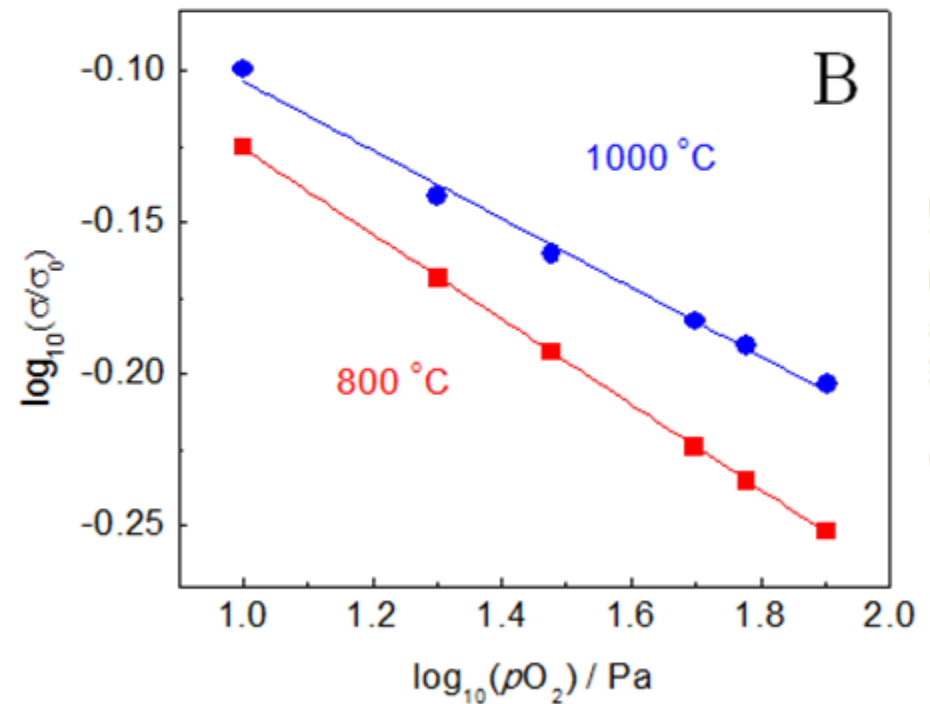
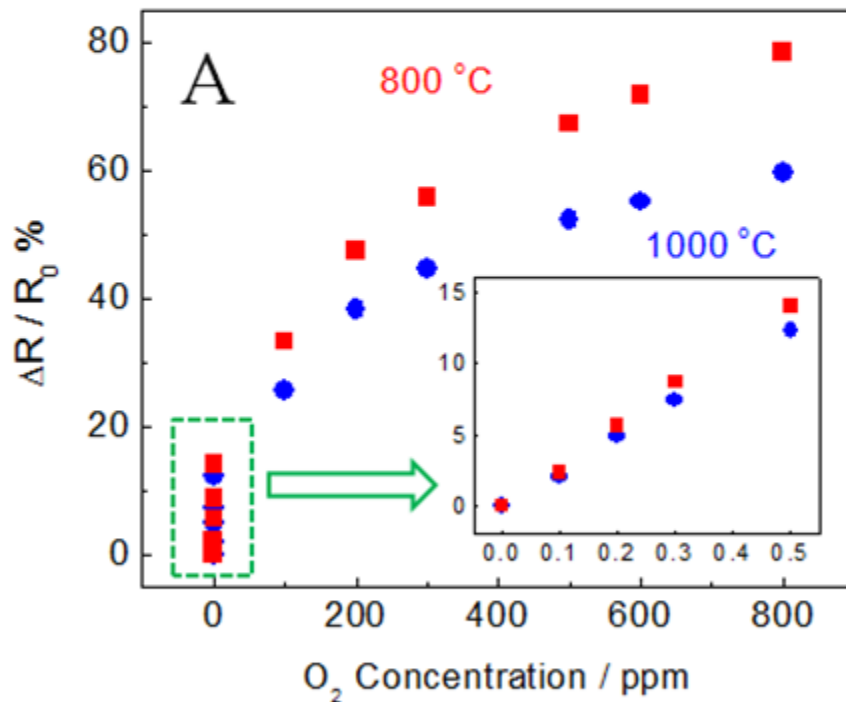
• CO



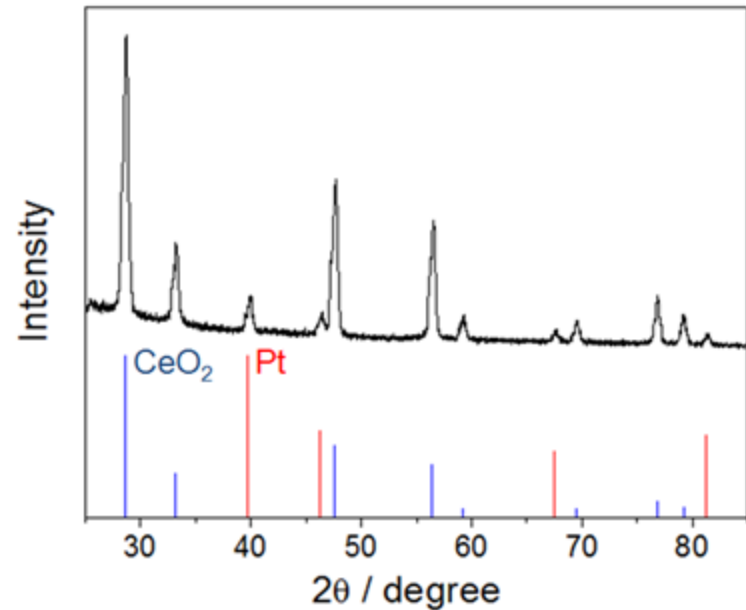
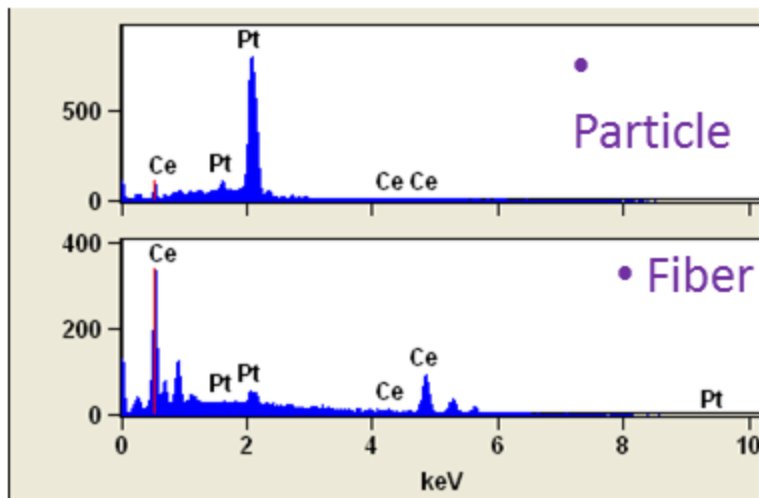
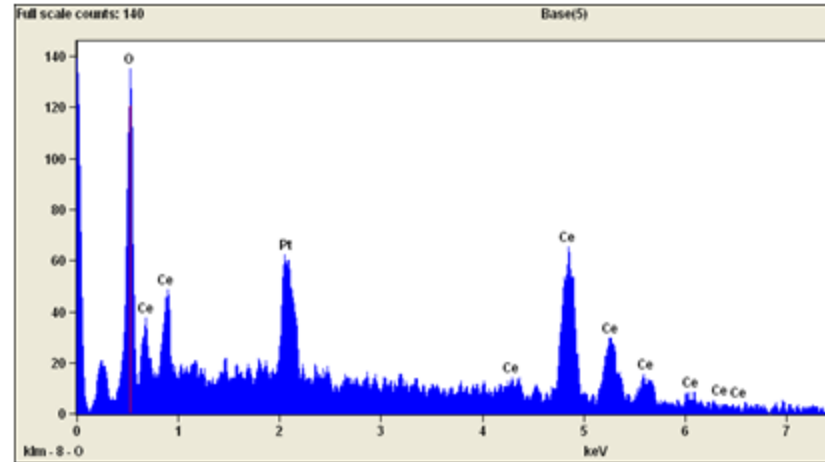
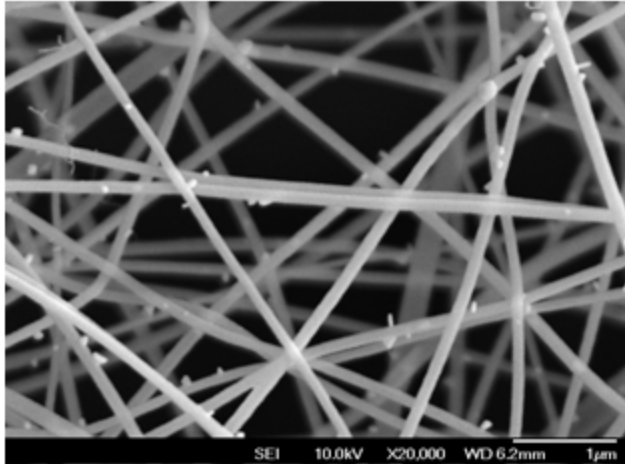
CeO₂ nanofibers sensors

– O₂ & CO sensing

- O₂: Calibration curves



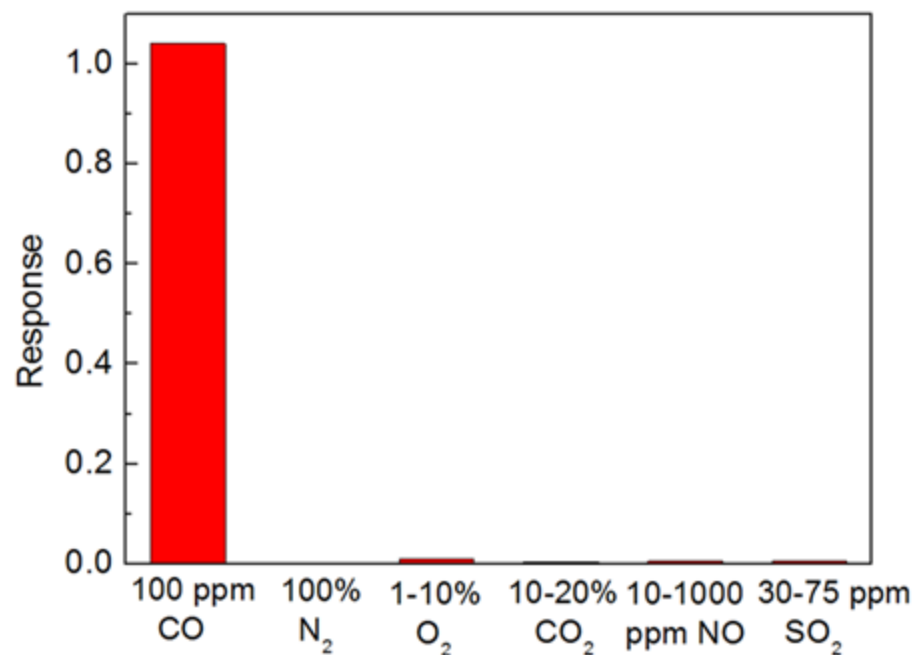
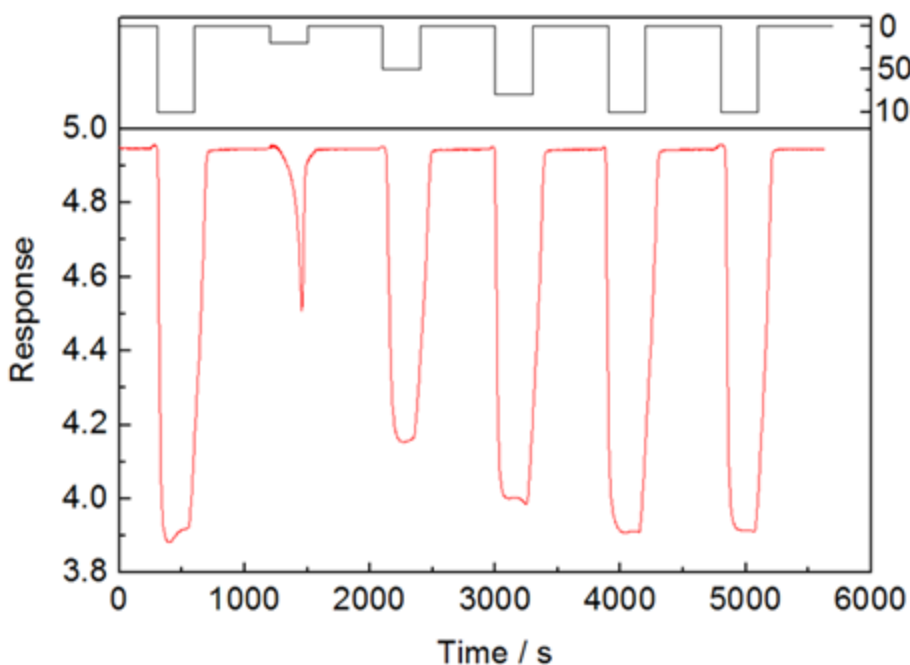
Pt-CeO₂ nanofibers – Characterization



Pt-CeO₂ nanofibers sensors

- Highly selective CO detection

- 800 °C gas detection

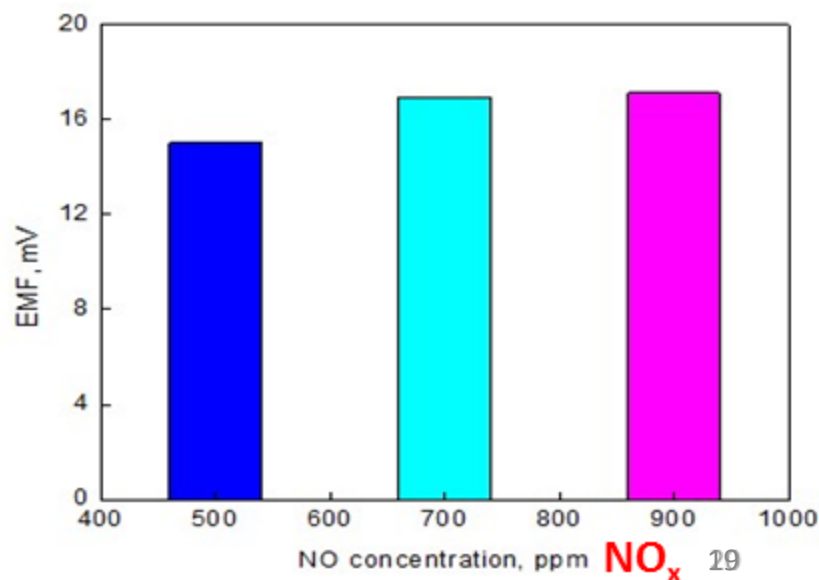
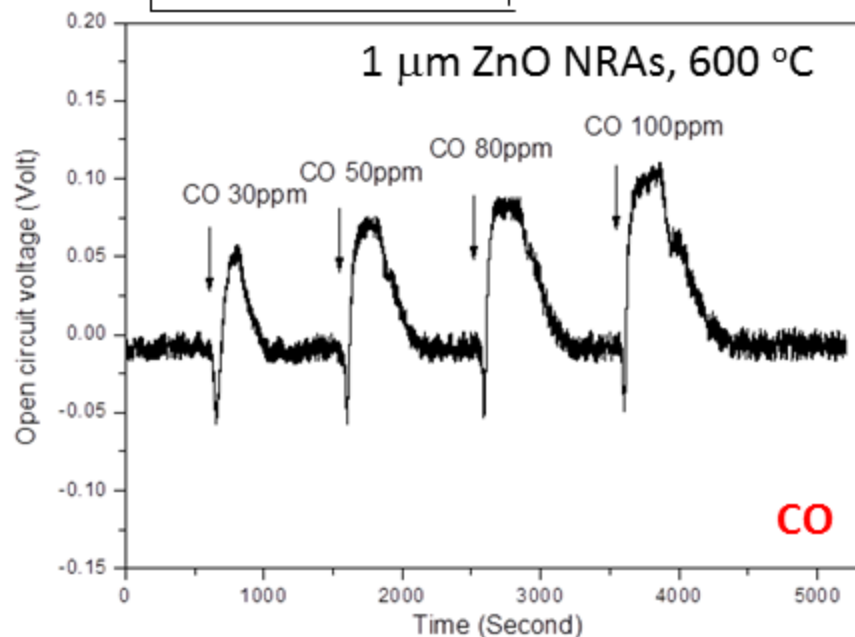
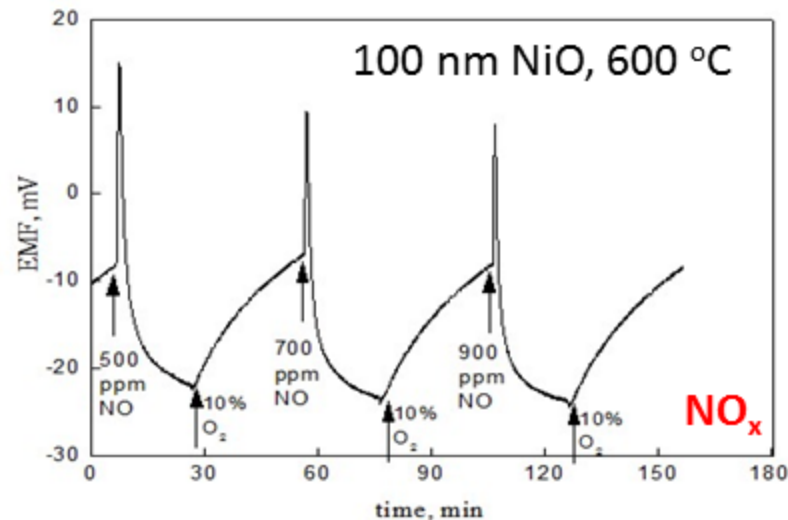
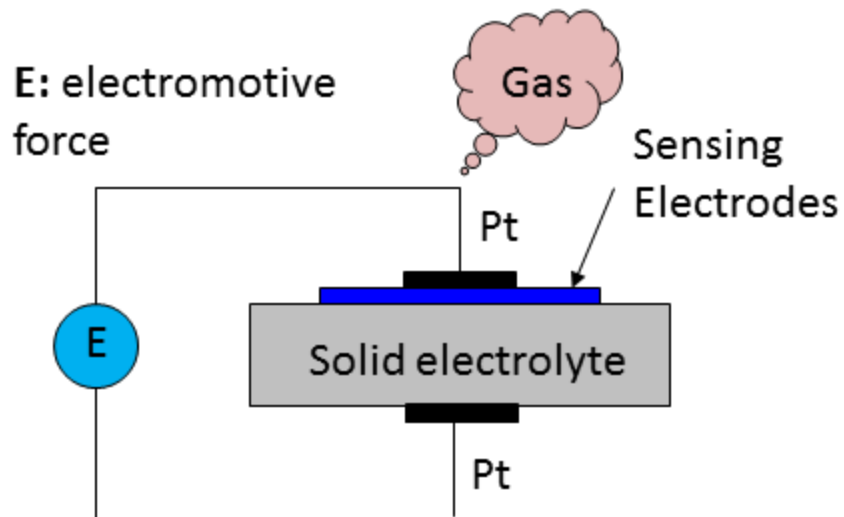


Liu et al., 2012, Anal. Chem., In preparation

Liu et al., 2012. Patent Application, In preparation

Nanostructured bimodular sensor platform

Potentiometric testing



Project Deliverables

ID	Title/Description	Planned Completion Date	Finished? (Y/N)
D1	Quarterly Report	1/30/09	Y
D2	Quarterly Report	04/30/10	Y
D3	Quarterly Report	07/30/10	Y
D4	Quarterly Report	10/30/10	Y
D5	Quarterly Report	1/30/11	Y
D6	Draft Final Report – BP1	2/02/11	Y
D7	Final Report – BP1	4/30/11	Y
D8	Quarterly Report	7/30/11	Y
D9	Quarterly Report	10/30/11	Y
D10	Quarterly Report	1/30/12	Y
D11	Draft Final Report – BP2	03/30/12	
D12	Quarterly Report	4/30/12	
D13	Quarterly Report	7/30/12	
D14	Final Report – BP2	10/30/12	20

Acknowledgement

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