Novel ZnO Nanorod Hydrogen Gas Sensors

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Start Date = January 1, 2005
Planned Completion = March 31, 2007

Research Goals and Objectives

- Develop the growth of high quality ZnO nanaowires for fabrication of low power hydrogen gas sensors
- Work with other team members to integrate sensor with wireless communication circuit and energy harvesting device.
  - Novel nano-sensor devices to improve sensitivity, reliability, and robustness, while reducing power consumption.
  - High efficiency and low power wireless communication circuit.
  - Self-powered by energy harvesting devices for energy efficient, long lifetime operation.

Relevance to Current State-of-the-Art

- Current detectors are generally based on thin films. Nanowires are expected to have lower power consumption and higher detection sensitivity based on their small size but large surface-to-volume ratio.
- We also should be able to optimize the detection sensitivity for hydrogen by controlling the properties of the nanowires

Relevance to NASA

The ability to detect ppm-level hydrogen at room temperature using low power, simple robust sensors is a critical safety issues in the detection of fuel leaks in spacecrafts and during the production, storage and transport of hydrogen

Budget, Schedule and Deliverables

- Budget $70K in FY04
- Collaboration of 4-men team (Norton-materials, Pearton-processing, Ren-processing, Lin-wireless circuits and integration)
- Deliverables: A prototype of integrated nanorod sensor, detailed schematics, simulation of the sensor performance, and test result.

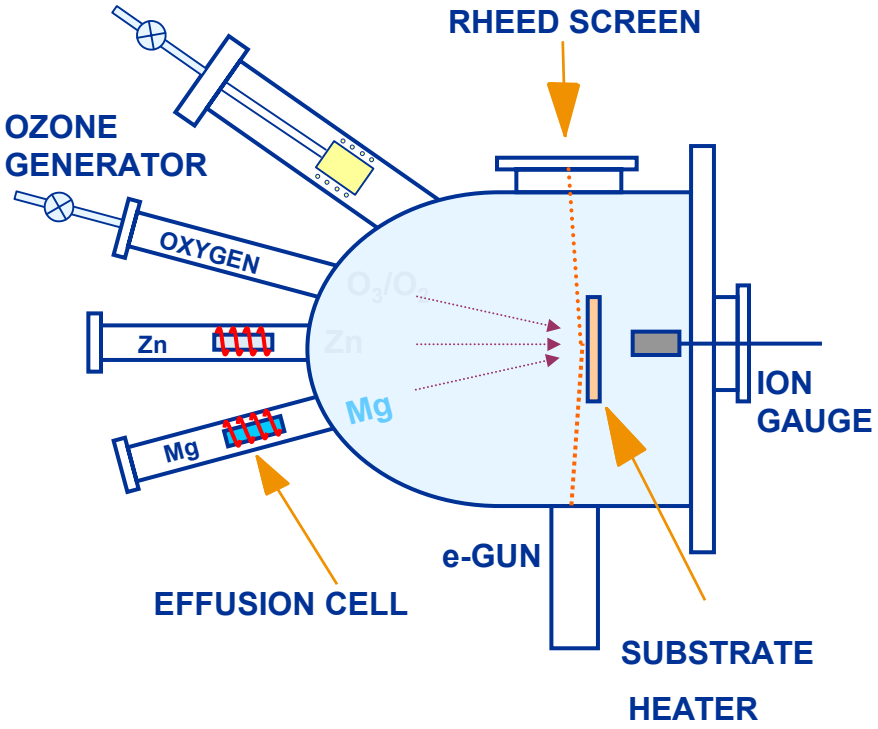
Anticipated Technology End Use

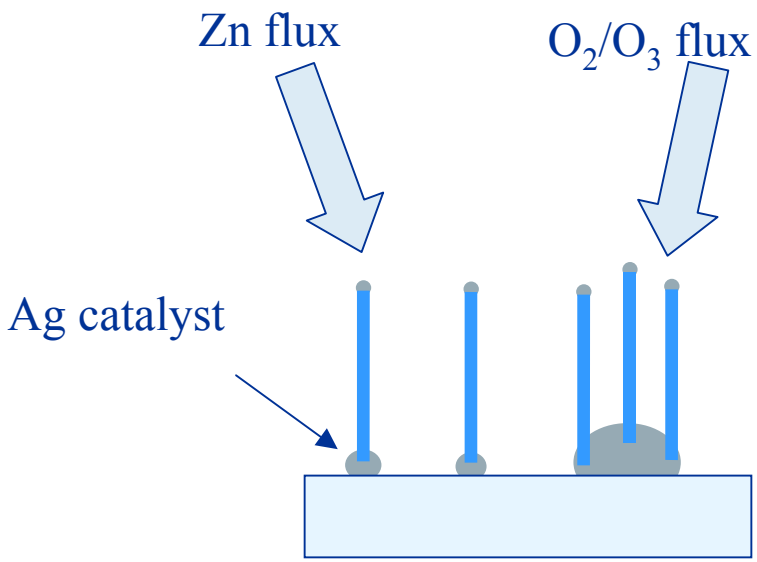
- Distributed wireless sensor network with low power consumption, small size, lightweight, low cost, long lifetime, low maintenance effort
- Low power, small size, lightweight, low cost → Nano-sensors and Nano-electronics
- Long lifetime, low maintenance → Self-powering.
- → Self-powered wireless hydrogen sensor

Accomplishments and Results

- Developed straightforward and reproducible method for site-selective growth of ZnO nanorods
- Supplied nanorods to other team members for fabrication of both single and multiple nanorod sensors
- The sensors show detection sensitivities of ppm of hydrogen in air at room temperature and do not respond to oxygen at this temperature
- The power consumption of the nanowire sensors is very low compared to conventional thin film sensors and is in the mW range.

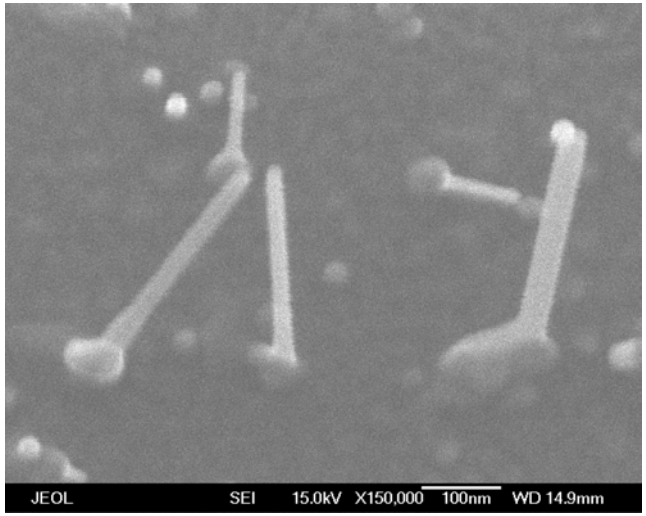
Site-Selective MBE of ZnO nanorods



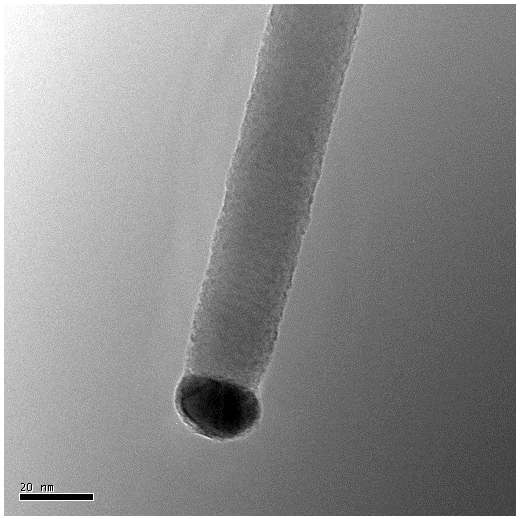


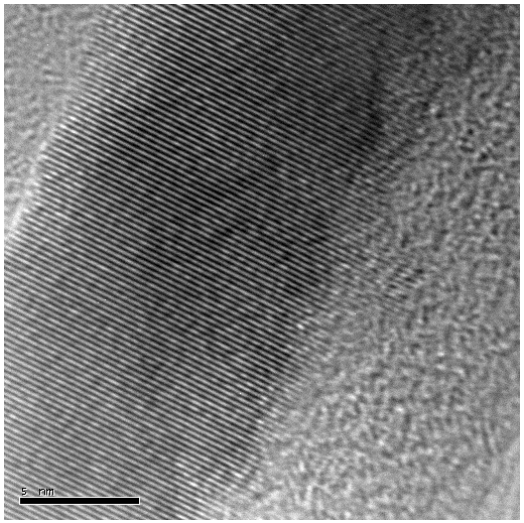
Growth Conditions for Nanorods

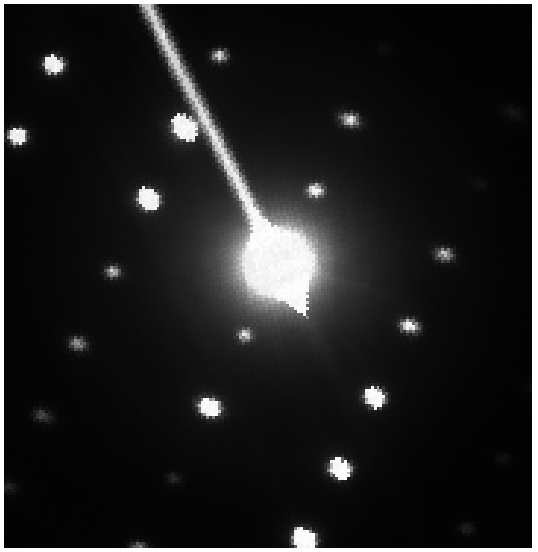
- Growth of ZnO on Ag-coated Si via MBE.
- Nominal Ag film thickness: 20 ~ 200 Å.
- (Coalesce into islands at growth temp.)
- Oxygen source: ozone/oxygen mixture
- Growth Temperature: 300 °C ~ 600 °C.



Single Crystal Nanowires



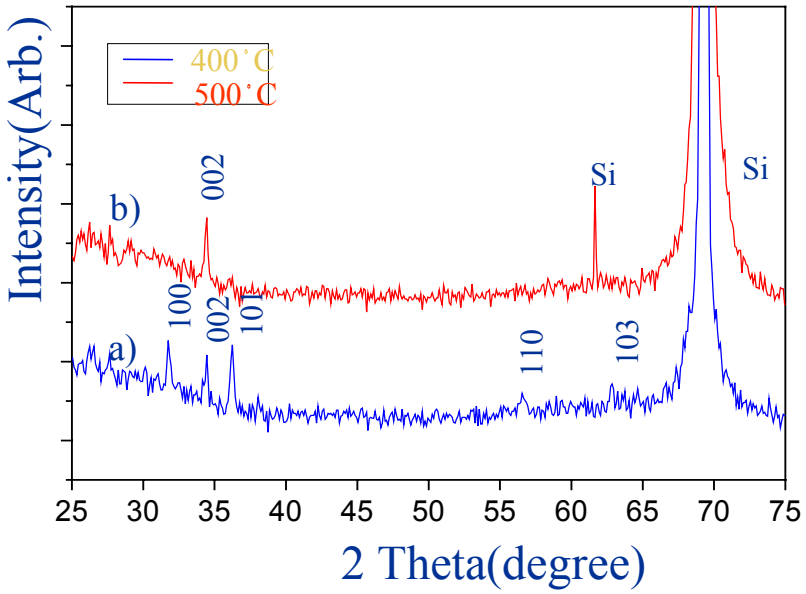


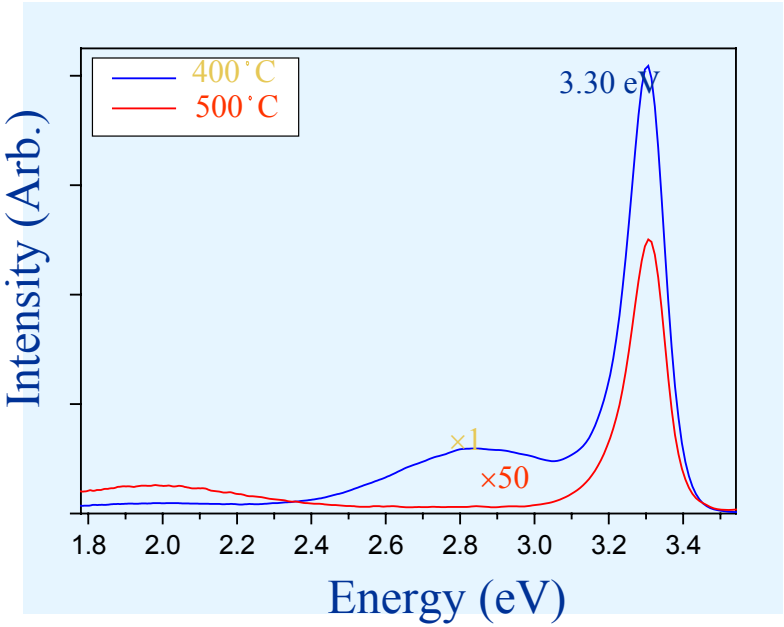


TEM image of an individual ZnO Nanowire.
An estimated diameter of the wire is 20 nm.
A small particle embedded at the tip of the wire is Ag or Ag-Zn alloy.
HR-TEM image and selected area diffraction (SAD) of the nanowire indicates that it is a single crystal ZnO.

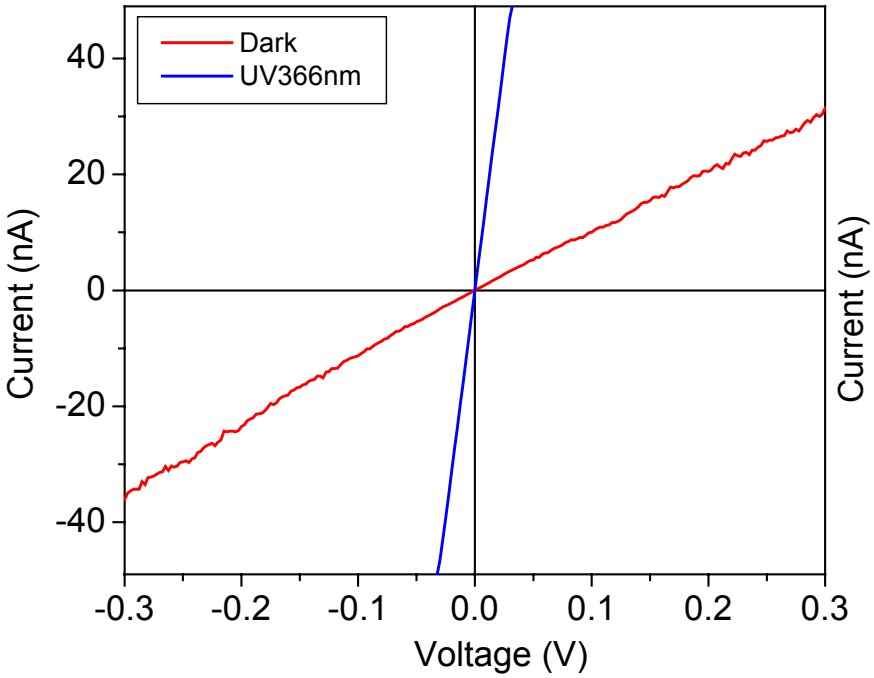
Excellent material quality

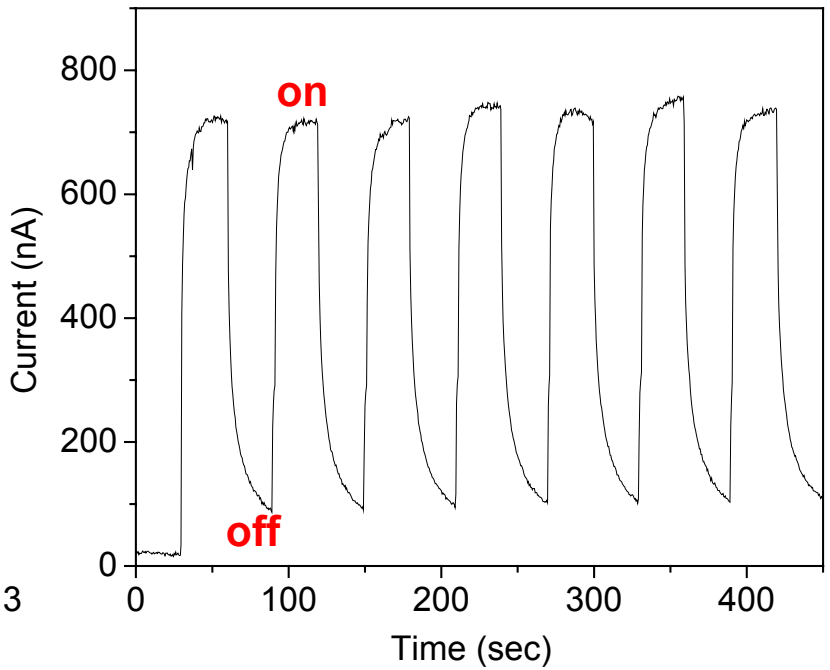
- PL of nanowires show strong near band-edge emission, with some deep-level emission.
- Preferred orientation of nanowires along the c-axis @ Tg 500˚C(b).
- Diffraction pattern looks like randomly-oriented polycrystalline material @ Tg 400˚C(a).



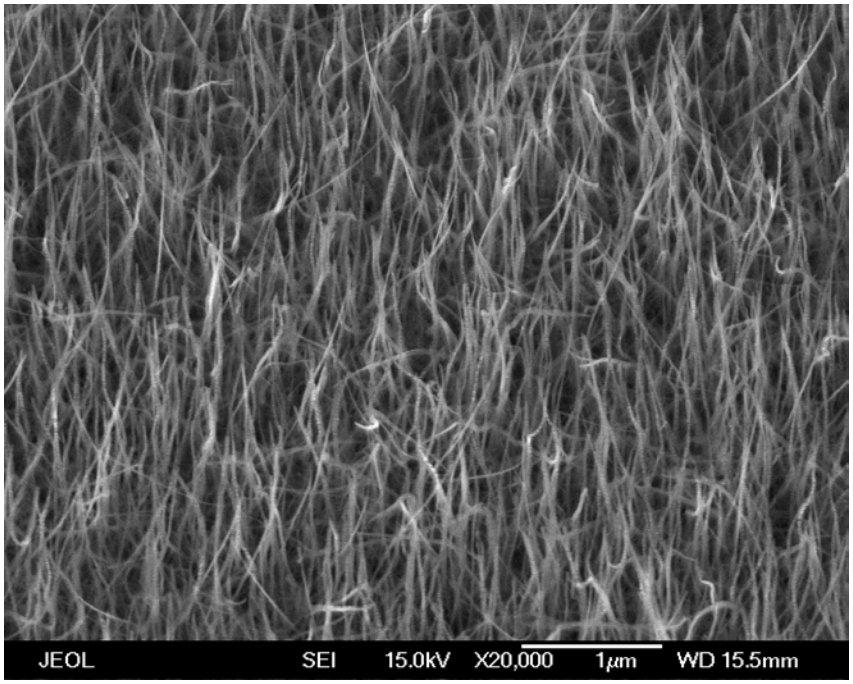


Strong UV photoresponse from nanorods-high quality material





Hydrogen-Selective Sensing at Room Temperature with ZnO Nanorods



Future Plans

- Compare O-terminated versus Zn-terminated nanorods in terms of their sensitivity for hydrogen detection.
- growth of cored ZnO/(Zn,Mg)O heterostructured nanowires- these are expected to give us added flexibility in terms of improving the detection sensitivity, recovery characteristics and long-term stability.
- Work with other team members to produce the integrated sensor/wireless system.