ZnO Nanowire Radiation Detectors with High Spatiotemporal Resolution

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**Motivation**
- Faster scintillator response = greater spatial resolution
- ZnO Nanowire Properties:
  - ZnO: Efficient photonic material
  - Direct bandgap of 3.37 eV
  - Very stable band-edge exciton (\(E_{\text{hv}}\)) (60 meV)
  - Typical photoluminescence (PL) spectra:
    - High-energy photon incident upon an electron
    - Electrons are being freed from F\(^+\) centers
    - F\(^+\) centers initially caused a blue shift and an increase in intensity in the PL visible emission
    - Over time visible emission peak red shifted and lowered in intensity, eventually returning to near baseline
    - Electrons are being freed from F\(^+\) centers, resulting in stable V\(^+\)
    - There was no significant change in the band-edge emission as a result of gamma radiation
    - ZnO NWs show the ability to ‘heal’ themselves of radiation damage, making them a promising gamma radiation detector

**ZnO Nanowire Growth**
1. 500 \(\mu\)m thick fused silica substrate cut to approximately 1 cm x 2 cm with diamond saw
2. Electron-beam evaporation used to deposit 100 nm ZnO seed layer on substrates
3. Substrates placed onto two Si wafer shelves in quartz tube. Zn source placed in crucible at bottom
4. \(Ar\) gas (800 SCCM) used to purge system of ambient air
5. \(O_2\) flow (30 SCCM) established and tube transferred to vertical furnace preheated to 690 °C
6. After 5 minutes, \(Ar\) flow rate reduced to 200 SCCM to allow \(O_2\) reach below the substrate
7. ZnO nanowires begin growing from seed layer

**Experimental Procedure**
- ZnO NW sample placed in irradiation chamber where it is bombarded with gamma rays from Cs-137 source
- Cs-137 emits 3.215 x 10\(^{10}\) 662 keV gamma rays per second per gram
- Rough calculation on number of events in irradiated ZnO NW sample
- Sample kept under dark conditions to minimize UV interaction
- Photoluminescence spectroscopy (PL) was performed each day following irradiation for 5 days
- Enabled analysis of changes in the band edge emission and visible emission as a function of time

**F\(^+\) Center Formation**
- 662 keV gamma rays interact with matter predominantly through Compton scattering
- Compton Scattering:
  - High-energy photon incident upon an electron
  - Electron emits a photon of lower frequency and is ejected from the atom, leaving a hole

**Photoluminescence Results**

**Future Work**
- Examine effects of UV exposure on visible emission of irradiated sample – potential fast “healing” of F\(^+\) centers
- Irradiate sample for much longer time to determine if gamma irradiation causes unhealable damage
- Compare ZnO NW gamma ray detection efficiency with typical detectors such as LYSO
- Study the damage effects of charged particle irradiation on ZnO NWs
- Coal ZnO NWs with MgO to passivate O\(^2-\) vacancy surface states

**Conclusions**
- F\(^+\) centers (\(V\(^+\)) were generated in ZnO NWs by gamma radiation and migrated by diffusion to the surface
- The increase in F\(^+\) centers initially caused a blue shift and an increase in intensity in the PL visible emission
- Over time visible emission peak red shifted and lowered in intensity, eventually returning to near baseline
- Electrons are being freed from F\(^+\) centers, resulting in stable V\(^+\)
- There was no significant change in the band-edge emission as a result of gamma radiation
- ZnO NWs show the ability to ‘heal’ themselves of radiation damage, making them a promising gamma radiation detector

**Acknowledgements**


**References**


**Images from**
- Nanowire Radiation Detectors with High Spatiotemporal Resolution
- Ryan Nolen
- www.showme.com