

# PHD DISSERTATION DEFENSE

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**1:00 - 3:00 p.m.**  
**C103 Engineering Research Complex**  
**(ERC Conference Room)**

## **"RADIATION RESILIENCE IN REDUCED DIMENSIONALITY SYSTEMS"**

### **ABSTRACT**

Space-based electronic systems such as communications satellites and interplanetary space probes have become increasingly important since their inception in the mid 20<sup>th</sup> century. However, as these systems become smaller and more sophisticated, the ability to carry radiation shielding to protect against the space radiation environment becomes more difficult. Therefore, new lightweight, radiation resilient electronics are needed to meet the demands of new probe designs. Current silicon based transistors rely on charged separated regions prone to radiation, which can disrupt normal operation. Novel nanomaterials that may be inherently radiation resilient offer promising alternatives. Recent research suggests that nanomaterials and nanomaterial based electronic devices may have inherent radiation resiliency due to their reduced dimensionalities, and in some cases enhanced self-healing due to their nanoscale sizes.

Low to high-Z, including krypton-86, krypton-78 and calcium-48, heavy ion irradiation experiments were conducted to explore fundamental heavy ion-nanomaterial interactions. Nanomaterials irradiated included carbon nanotubes, gallium nitride (GaN) nanowires and carbon onions. GaN nanowire-based circuit operation in radiation was also investigated using special vault facilities that enabled real-time testing. Results were highly encouraging and promise high payoff, given their high radiation resilience and superior materials and electronic performance.

The GaN nanowires used in radiation investigations were unique multiphase nanowires with zinc-blende and wurtzite crystalline domains that grew simultaneously in the longitudinal direction. A new catalyst-free vapor-solid growth method was used to obtain the multiphase nanowire structure. Electronic and structural properties of the multiphase nanowires were conducted. Plain-view high-resolution transmission electron microscopy (HRTEM) was used to identify the presence of both the zinc-blende and wurtzite crystalline phases present in the nanowire. Cross-section HRTEM was used to identify the crystalline domain orientation relationships and coherent and incoherent interfaces between domains within the nanowire. Scanning

electron microscopy (SEM) investigations identified nanowire matrix formation dependence on growth temperature. HRTEM investigations of the sides of hexagonal platelets that formed on the matrix, from which nanowires grew, revealed a network of nanoscale ledges. These ledges were identified as probable nanowire nucleation sites.

Electronic investigations of an individual nanowire using nanomanipulator probes accurately measured the nanowire resistance using four-point probe techniques. The same nanomanipulator probes were used in a two-point probe configuration and evidence of phase-specific transport was observed. GaN nanowire-based field effect transistors were also fabricated and their I-V characteristics measured. All measurements indicated that the nanowires were capable of carrying high current densities. Cathodoluminescence measurements identified unique band gaps for both the zinc-blend and wurtzite phases in an individual nanowire. A large blue shift in each band gap relative to bulk GaN indicated significant strain and possible electron confinement effects in the nanowire. The multiphase structure represents a new class of nanowires with possible applications in electron and photon confinement and high power applications. The catalyst-free vapor-solid one-step method simplifies growth, making new and complex nanowire structures easier to achieve.

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