Nitride materials and interfaces for radiation-hard integrated neutron detection

Nancy M. Haegel PI

National Renewable Energy Laboratory

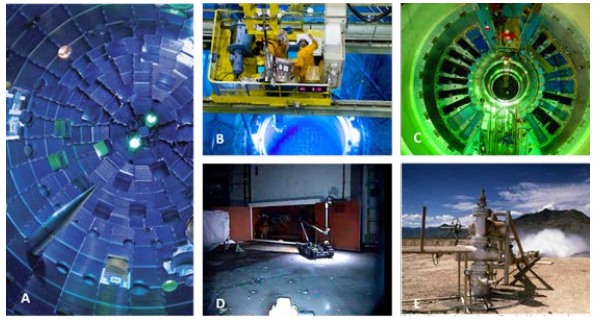
ERI Summit

October 20, 2021

Project goals

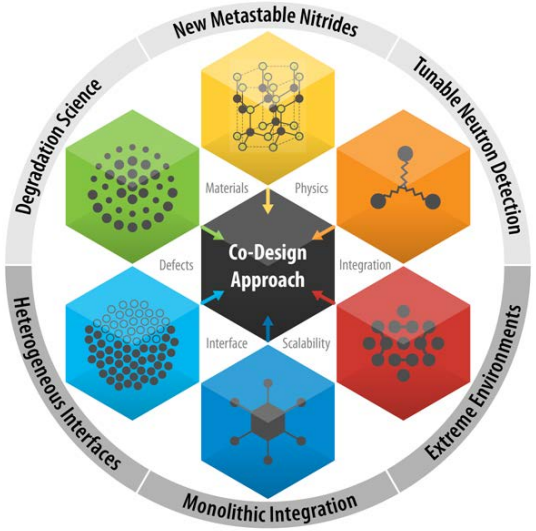
Goal: Develop new UWBG ternary nitride materials for radiation tolerant neutron detectors, understand stability and defect behavior, and demonstrate device functionality

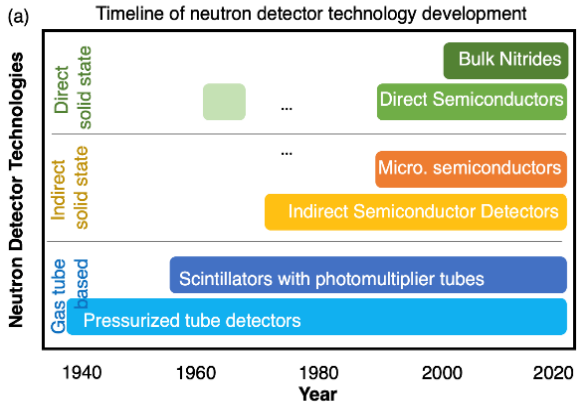
Hypothesis: Coupling the strongest-known neutron capture cross section of ^{157}Gd with the transport properties and demonstrated radiation tolerance of nitride semiconductors will ***advance both absorption and transport properties compared to state of the art***, with potential for monolithic integration and imaging

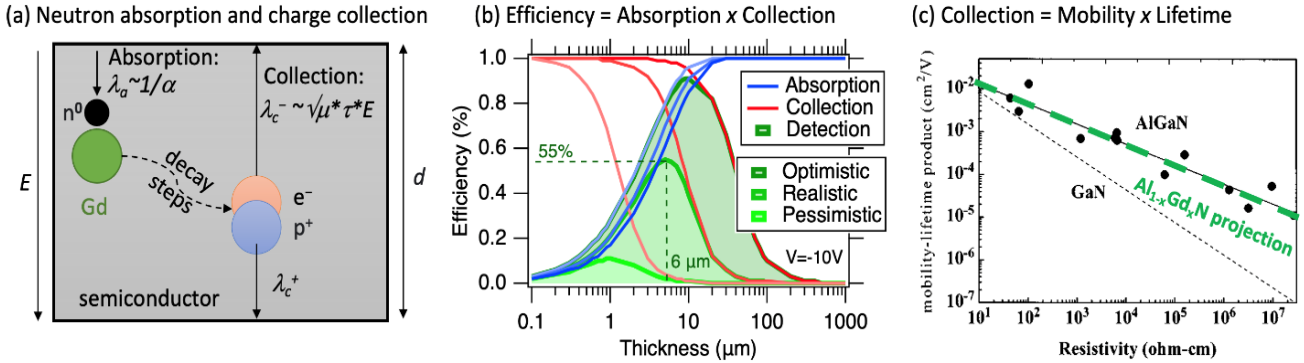


Fission and fusion research, nuclear reactors, geothermal borehole imaging, nuclear medicine, materials characterization, nuclear incident response

Co-Design Challenge: a material to fully meet the need for both efficient neutron conversion and charge collection, as well as additional co-design criteria for manufacturability and durable operation in extreme environments.







Key scientific challenges and team capabilities

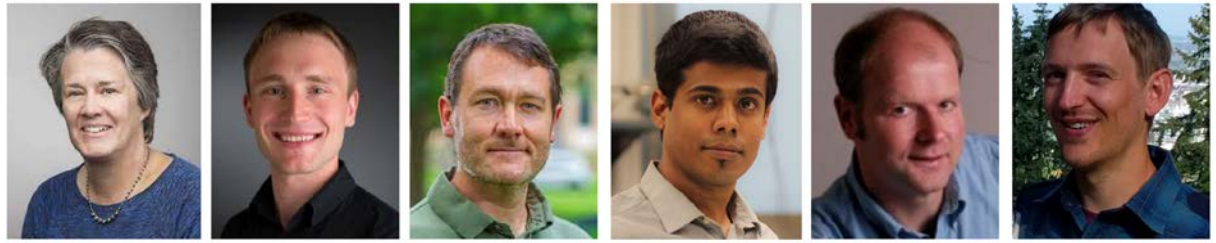
Key challenges:

- Synthesis of new metastable AlGdN alloys
- Design electrode materials and demonstrate heteroepitaxial integration
- Study behavior under irradiation; understand stability and defect formation

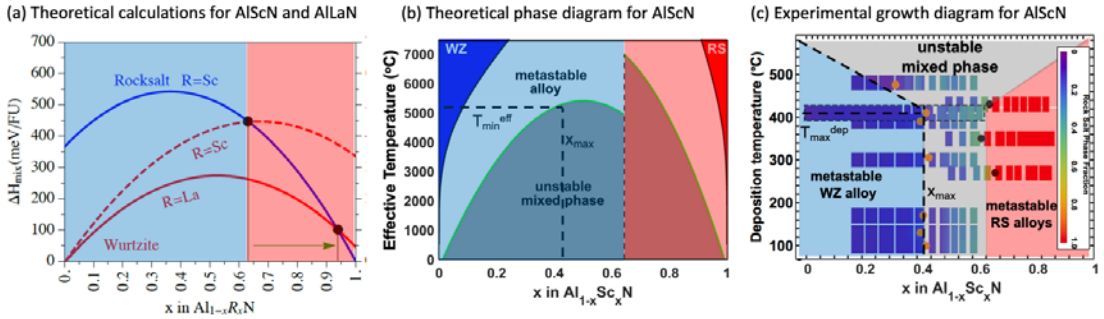
Capabilities to address these challenges:

- Novel nitride growth
- Integration of theory and experiment
- Multimodal materials characterization
- Ability to study material response and prototype device behavior in the detection environment

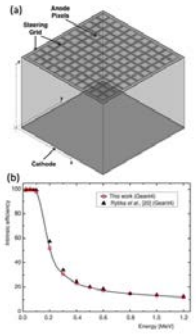
Nancy Haegel (PI) | Andriy Zakutayev | Geoff Brennecka | Prashun Gorai | Kai Vetter | Sage Bauers

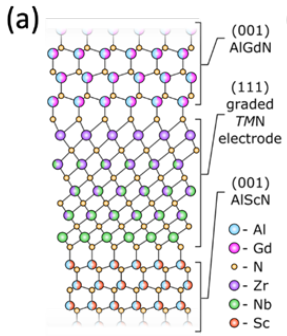


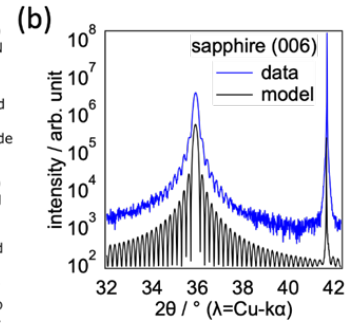
Expertise in novel nitride growth, theory and computation, materials integration and device functionality, sensor physics and applications

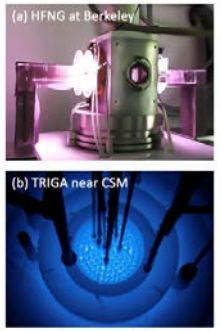


K.R. Talley et. al., Implications of heterostructural alloying for enhanced piezoelectric performance of (Al,Sc)N, Physical Review Materials, 2 (2018) 063802.









Recent advances and opportunities to partner

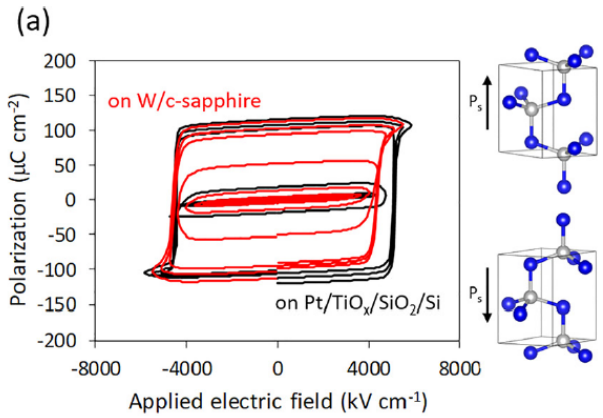
Recent results/trends relevant to ERI

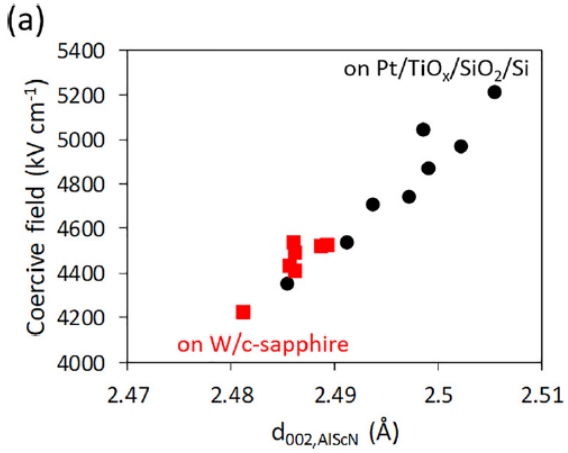
- Class of pseudo-binary alloys and ternary nitrides is rapidly expanding due to advances in high-throughput computational discovery and non-equilibrium experimental synthesis
- WBG nitride semiconductor "devices are now being integrated at higher level of hierarchy in integrated circuits"; Decadal Semiconductor Report calls for continuation of this trend
- Team recently demonstrated the first fully epitaxial ferroelectric wurtzite $Al_xSc_{1-x}N$ film with large coercive field (4 MV/cm), even larger breakdown field (>5 MV/cm), and strong polarization (>100 $\mu C/cm^2$)

Opportunities to partner

- Collaborations on synthesis of novel materials
- Opportunities to develop non-equilibrium low temperature plasma synthesis
- Potential for fully integrated thin film detection
- Identification of sensor needs and detection scenarios
- Need for breadth of expertise and capabilities to take future steps toward integration, scalability and manufacturing

Partner in novel nitride applications



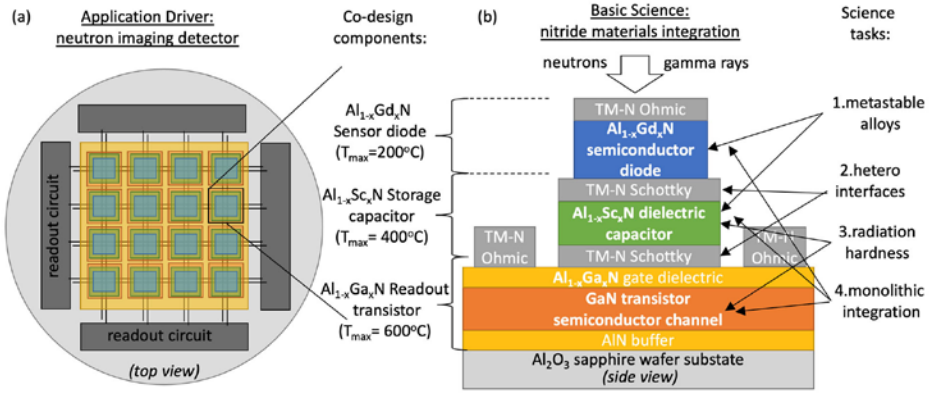


Reduced coercive field in epitaxial thin film of ferroelectric wurtzite $Al_{0.7}Sc_{0.3}N$

Cite as: Appl. Phys. Lett. 118, 162903 (2021); doi: 10.1063/5.0043613
Submitted: 10 January 2021 · Accepted: 31 March 2021 ·
Published Online: 21 April 2021

View Online

Keisuke Yazawa,[1,2,a)] Daniel Drury,[1,2] Andriy Zakutayev,[1] and Geoff L. Brennecka[2,a)]



Realize an integrated sensor vision

Thank you

www.nrel.gov

Nancy M. Haegel

Materials Science Center

NREL/PR-5K00-81334

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Science, Basic Energy Sciences. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY