Energy Frontier Research Center for Solid-State Lighting Science (SSLS)
EFRC Director: Michael E. Coltrin
Lead Institution: Sandia National Laboratories

Mission Statement*: To explore energy conversion in tailored photonic structures and materials to enable revolutionary breakthroughs in the efficiency and performance of light emitting diode (LED)-based lighting; to improve energy-efficiency in the way we light our homes and offices, which currently accounts for 20 percent of the Nation's electrical energy use. Solid-state lighting has the potential to cut that energy consumption in half, or even more.*

The overarching theme of our EFRC is the *exploration of energy conversion in tailored photonic structures*, a theme that is at the heart of solid-state lighting and other energy technologies, and a theme of major scientific interest as discovery-class research. We have organized the EFRC into three scientific Thrusts. Within each Thrust are specific research projects, which we refer to as "Challenges."

Our first scientific Thrust is: **"Competing Energy Conversion Routes in Light-Emitting InGaN."** In this Thrust, we are studying wide-bandgap materials and the complex interplay between their defect and luminescent properties. The first Challenge within this Thrust is "Point Defects in InGaN: Microscopic Origin and Influence on Luminescence," in which we seek to understand the relationship between specific material defects, their dependence on various synthesis conditions, and the production or suppression of InGaN luminescence. The second Challenge is "Radiative and Non-Radiative Processes in the High-Carrier-Density Regime," where we seek to understand radiative efficiency, which is due to the competition between radiative pathways and undesirable non-radiative pathways that produce heat instead of light. For InGaN materials, there is a complex array of potential non-radiative processes that presently limit the radiative efficiency but are very poorly understood.

Our second scientific Thrust is **"Beyond Spontaneous Emission."** In this Thrust, we are studying energy conversion routes in subwavelength photonic structures in which electromagnetic fields are stronger or more localized, and photonic densities of states can be more exquisitely controlled, than in structures typical of current solid-state-lighting technology. Such extreme conditions are scientifically interesting in their own right, as vehicles for the science of coherent, many-body phenomena. And, as new energy conversion routes are explored, entirely new solid-state-lighting materials structures may arise from their understanding. The first Challenge area is "Strongly Coupled Exciton-Photon Systems," in which we are exploring strong coupling between excitons and photons in optical microcavities containing active wide-bandgap GaN-based materials. The second Challenge is "Surface Plasmonic Intermediaries to Exciton-Photon Interactions," in which we are exploring the possibility that surface plasmons, with their strong confinement and greatly enhanced local electromagnetic fields, might someday be useful as intermediaries in the energy conversion process from excitons to free-space photons.

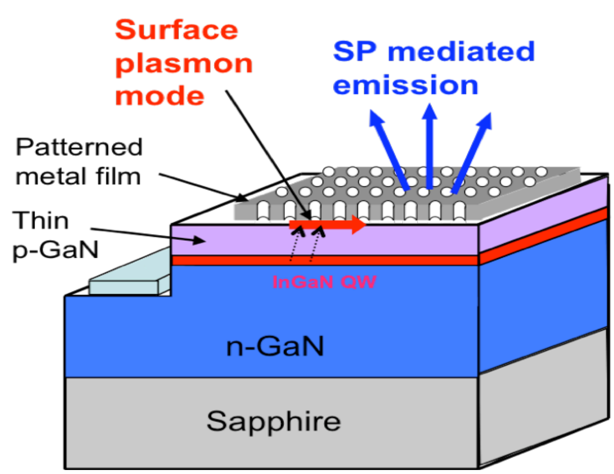

Figure 1. Plasmonic LED structure.

Our third scientific Thrust is **"Beyond 2D."** In this Thrust, we study energy conversion routes in 1D and 0D nanostructures that go beyond the conventional 2D planar heterostructures typical of solid-state lighting technology. These nanostructures are scientifically interesting in their own right, as vehicles for the science of the very small, and for studying how energy quantization and conversion are influenced by dimensionality and proximity to surfaces and interfaces. Also, because of fundamental differences in how lower dimensional structures are synthesized and how they accommodate lattice mismatch and strain, these structures allow study of defect-mediated energy conversion routes different from those occurring in traditional 2D heterostructures. The first technical Challenge in this Thrust is "Nanowires: Synthesis and Properties of Radial Heterostructures," in which we explore the relationship between the synthesis and resulting composition and microstructure of 1D nanowires, with an emphasis on developing the ability to tailor the densities of particular kinds of point and extended defects. The second Challenge is "Nanodots: Nonlinear Luminescence Dynamics," in which conversion of charged carriers into photons can be extremely efficient, but is also strongly influenced by particle size, microstructure, surface functionalization, and chemical environment.

Throughout this EFRC, our emphasis is on fundamental science enabled by integrated, interdisciplinary capabilities: linking state-of-the-art nano-materials design, synthesis and characterization; linking theory and experiment; and linking scientific understanding of isolated phenomena studied in model systems with empirical observations that are found in relevant technology platforms. Advances in nano-fabrication and nano-characterization enable such explorations in unusual nanostructure compositions and instantiations, and under experimental conditions specifically tailored to expose particular energy conversion processes. Building on our strengths in tool creation and allied technologies, we also place an emphasis on research tools (synthesis, characterization, and modeling) that both draw upon science and can be used to enable scientific investigations.

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