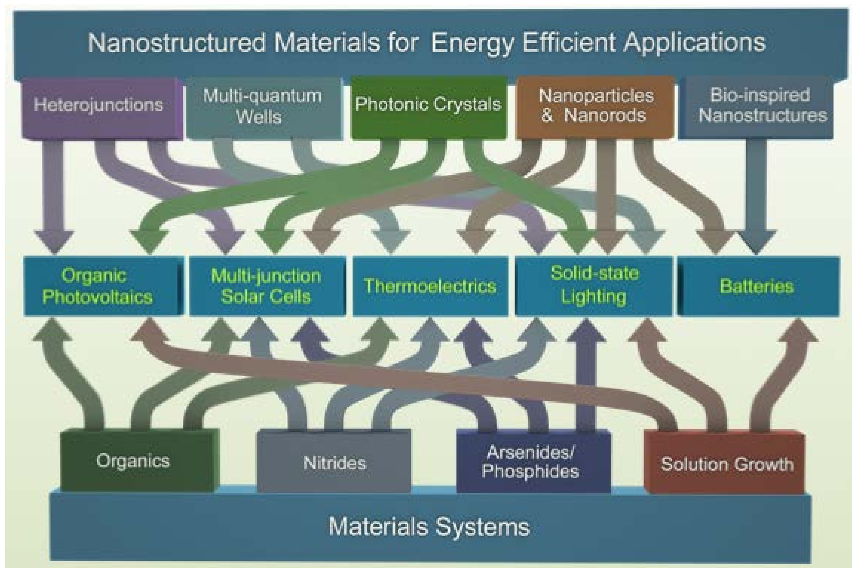
Center for Energy Efficient Materials (CEEM)
EFRC Director: John E. Bowers
Lead Institution: University of California, Santa Barbara

Mission Statement*: To discover and develop materials that control the interactions among light, electricity, and heat at the nanoscale for improved solar energy conversion, solid-state lighting, and conversion of heat into electricity.*

The Center's research program is highly cross-disciplinary and is organized into teams, each having extensive expertise in materials growth, characterization, theoretical modeling; and device design, fabrication, and characterization. These collaborative teams encompass multiple disciplines and multiple institutions: UC Santa Barbara (lead), Purdue University, the National Renewable Energy Laboratory, and the Los Alamos National Laboratory. CEEM's core strength is the unique capabilities of UCSB and its partner institutions to control, synthesize, characterize, and apply materials at the nanoscale for more efficient sustainable energy resources. This expertise is a central theme that unites all the work of the Center and drives the synergy among the various task groups, as illustrated by the accompanying figure. Although the center's primary focus is basic research, its longer-term objective is to transfer new materials and devices into the commercial sector to impact the nation's need for sustainable energy resources.



Organic Photovoltaics: As an overarching goal, the CEEM OPV group seeks to understand conjugated polymer and small molecule semiconductor blends that function as the active layer in solar cell devices. The effort brings together a cohesive and mutually complementary set of experts at UCSB, NREL and LANL to understand what may appear at first sight to be unrelated phenomena. Indeed, the collective CEEM OPV effort very recently led to the design, processing, structural characterization, theoretical understanding and device integration of new types of organic semiconductors, including well-defined molecules that exhibit record power conversion efficiencies.

High Efficiency Multijunction Photovoltaics: Our focus is on novel approaches to InGaN and multijunction photovoltaics for unprecedented high photovoltaic energy conversion efficiencies. This goal requires development of new techniques for the efficient simultaneous coupling of electrons and photons through the various junctions. One of the goals of the project is to develop a five-junction solar cell using a high-bandgap InGaN top junction in combination with a fully lattice-matched underlying arsenide-phosphide four-junction cell. This work requires that we develop new techniques to address the complex issue of designing and fabricating a multi-junction cell in which the optical, electrical, and mechanical properties of each junction are compatible and optimized to provide the highest possible overall efficiency.

Novel Nanostructured Thermoelectrics: Our Scientific objective is to develop new thermoelectric materials whose properties enable us to simultaneously increase the Seebeck coefficient and electrical conductivity, and reduce the electronic and lattice thermal conductivities. We explore a wide range of materials, including 1) semiconductors with nanocrystalline metallic inclusions, 2) new nitride thermoelectric semiconductor materials, 3) electrically conducting crystalline oxides, 4) fine ordered, patterned crystalline silicon nanowire arrays and 5) nanostructured chemical compounds and composites. This involves understanding and engineering the inclusion, transport and scattering of mobile charge carriers and the propagation and scattering of heat-carrying lattice vibrations in the materials, all of which are crucially dependent on the physical and electronic structure of the materials.

High-Power Batteries: Our goal is to develop and apply a new biologically inspired, low cost, low temperature approach to make nanocomposites with exceptionally high power and stability as anodes and cathodes for lithium ion batteries. In addition to the near-term application of the results of these studies for the improvement of batteries and related energy technologies, the broader impact of this research includes a deeper fundamental understanding of the factors governing the control of synthesis, assembly and performance of a wide range of semiconductors and other valuable inorganic materials, to enable their more economical and more efficient use for energy technologies including energy harvesting, transduction and storage.

Solid-state Lighting: Our goal is to advance the fundamental science and technology to both understand factors that limit efficiencies for light emitting diode-based lighting and to provide innovative and viable solutions to current roadblocks. We intend to achieve these goals by: (1) control and elucidation of the carrier loss mechanisms on nonpolar/semipolar GaN LEDs; (2) growth of defect-free bulk GaN crystals; and (3) full-spectrum lighting using an all semiconductor-based emission region; (4) grow devices on nonpolar or semipolar planes to avoid the detrimental effects of polarization-induced electric fields in multiquantum wells arising from discontinuities in spontaneous and piezoelectric polarization at heterointerfaces; and (5) develop and apply photonic crystals to enhance the extraction of light from LEDs.

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