Solid-State Solar-Thermal Energy Conversion Center (S^3TEC)
EFRC Director: Gang Chen
Lead Institution: Massachusetts Institute of Technology
Start Date: August 2009

Mission Statement*: To advance fundamental science and to develop materials for harnessing heat from the Sun and terrestrial sources and converting this heat into electricity via solid-state thermoelectric, thermophotovoltaic, and thermogalvanic technologies.*

The DOE EFRC center entitled "Solid-State Solar-Thermal Energy Conversion Center (S^3TEC Center)" is formed by the Massachusetts Institute of Technology, in partnership with Boston College, Duke University, the University of Houston, the University of Missouri, the Northwestern University, Brookhaven National Laboratory, and Oak Ridge National Laboratory. The S^3TEC Center was founded in 2009 with the vision to create an intellectual base for advancing the fundamental science of energy-carrier coupling and transport for thermal-to-electrical energy conversion, originally based on thermoelectric (TE) and thermophotovoltaic (TPV) technologies. The Center was renewed in 2014 with the expanded scope that now includes thermogalvanics (TG) and spin transport studies in addition to exploration of new phenomena in photon, phonon and electron transport, topological properties, and energy conversion mechanisms.

These heat-to-electricity energy conversion technologies represent a drastic departure from conventional thermal-mechanical energy conversion engines. They are solid-state and do not involve intermediate mechanical energy conversion. They are attractive for their compactness, scalability, and environmental friendliness, but currently are not efficient enough to compete against conventional energy conversion technologies. Since its inception, the fundamental knowledge gained at the S^3TEC Center has been successfully used to design new materials and to demonstrate proof-of-principle prototypes to achieve leaps in efficiency of these technologies, with an emphasis on approaches that have the potential to be low-cost. The S^3TEC Center's focus on fundamental studies of the transport of electrons, phonons, and photons, and the interactions among these carriers has led to improvements in material performance and promising technology demonstrations, including achieving 7.4% and 6.8% efficiencies of solar TE and solar TPV generators, respectively, which are significantly higher than prior state-of-the-art.

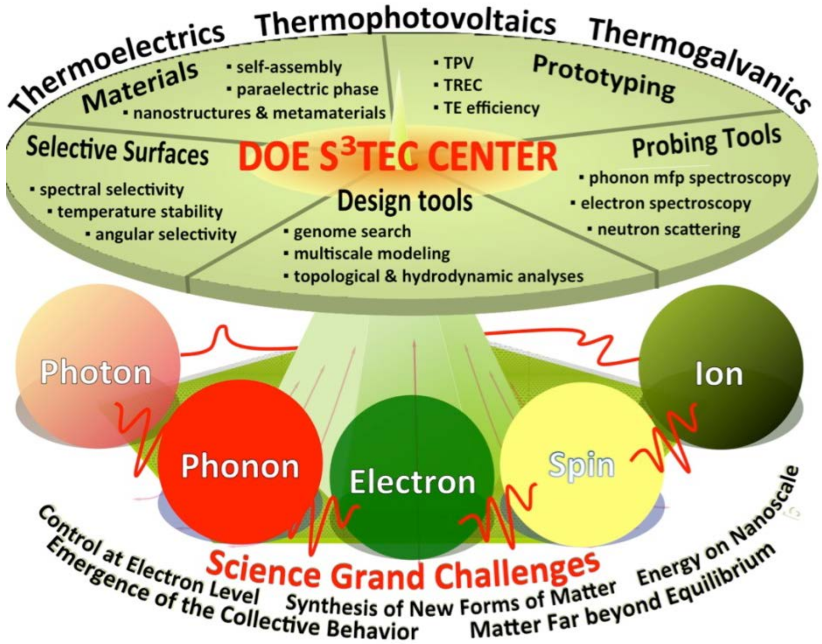

Figure 1. Vision of S^3TEC Center. The Center focuses on electron and spin, ion, phonon, and photon transport and interactions underpinning direct heat-to-electricity energy conversion based on thermoelectric, thermogalvanic, and thermophotovoltaic technologies. Addressing grand challenges yields new materials and methods for simulation and characterization.

The renewed S^3TEC Center not only builds on the progress made but also significantly expands its research horizons: harnessed energy sources include not only solar but also terrestrial heat; in addition to TE and TPV, thermogalvanics joined the list of pursued technologies through our proposed study on thermally regenerative electrochemical cycles (TREC); the fundamental energy carriers studied include not only electrons, phonons, and photons, but also ions and spin; the emphasis on computational material design and mesoscale simulation to guide material synthesis is increased; topological properties of electronic and photonic materials are explored for energy harvesting and conversion applications. Figure 1 illustrates the vision behind the S^3TEC center and the scope of research it encompasses.

TE, TREC, and TPV technologies have high potential for a transformative growth in our efforts to harness an almost endless energy supply from the sun and terrestrial heat sources. However, successful development of these technologies can be achieved only through fundamental breakthroughs in materials design and understanding of transport processes. While we know to a certain degree how to control photons, we know much less about how to control electrons and ions in this context, and very little about how to control phonons. Many fundamental questions and challenges lie ahead, and to address them, the S^3TEC Center strives to take our fundamental understanding to the logical next step: to designing materials and processes that can be scaled up, so that research can be applied to meet the energy challenges of our nation and the world.

The Center aims to address the DOE's grand challenges, connecting nanoscale materials to gigawatts electricity, by advancing the basic science underpinning direct energy conversion technologies, through discovering materials that meet the needs of applications in terms of performance, cost, and reliability. By studying TE, TG, and TPV technologies in one Center, great synergy is generated in basic science, technology, and applications. The Center advances and employs photon, neutron, and electron beams and first-principles simulation tools to enable the probing and understanding of the transport processes of the carriers and the prediction of their properties relevant for energy conversion.

This understanding will aid in the design and synthesis of materials to validate the theory and construct proof-of-principle prototypes demonstrating the potential to achieve high heat-to-electricity conversion efficiency. The S^3TEC Center builds on its established management structure, which continues to encourage and strengthen synergistic collaborations, nurture future leaders in energy technology, and engage the public through outreach activities.

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