Energy Frontiers Focus Topic
Room: 7 - Session EN+NS-ThA

Thermophotovoltaics, Thermoelectrics and Plasmonics
Moderator: R.A. Quinlan, Naval Surface Warfare Center, Cardercock Division

2:00pm **EN+NS-ThA1 Structuring of the Radiative Thermal Emission in Tungsten Inverse Opals for Thermophotovoltaic Applications**, ***M.D. Losego***, North Carolina State University, *K.A. Arpin*, University of Illinois at Urbana Champaign, *B. Kalanyan*, North Carolina State University, *P.V. Braun*, University of Illinois at Urbana Champaign, *G.N. Parsons*, North Carolina State University

Materials with photonic bandgaps are generated by periodic mesostructuring at length-scales comparable to visible wavelengths. While photonic bandgaps are often used to control the interaction of incident light with a material (e.g. reflect incident light over a narrow bandwidth), these structures can also be used to tune the thermal emission of light. Consequently, a heated metallic photonic crystal could be used in a thermophotovoltaic (TPV) device scheme. Such a TPV would (1) absorb broadband incident solar radiation, (2) heat up, and (3) re-emits the radiation over a narrow band of energies. This narrow-band radiation could then be converted to electricity with high efficiencies using a simple single-junction solar cell. However, demonstrating narrow-band thermal emission from a multidimensional architecture remains elusive. The central challenge is finding a materials set that demonstrates the required combination of thermal stability and dielectric function in a nanostructured architecture capable of high-temperature radiant emission.

This talk will examine our development of refractory tungsten inverse-opal structures designed for thermal emission in the visible spectrum. The first generation of these structures were constructed from silica opals infiltrated with electrodeposited tungsten. While ultrathin (<20 nm) oxide ALD layers were found to improve high temperature stability (>1000°C, 12 hours) by restricting surface diffusion and limiting sintering, difficulties with massive structural cracking during the molten-salt electrodeposition process could not be overcome. Second generation devices are now being developed using a lower temperature tungsten atomic layer deposition (ALD) process. Besides the avoidance of massive structural cracking, these ALD materials appear to be denser than electrodeposited materials, further reducing the unwanted sintering effects at high temperatures. Room temperature spectra collected from these structures indicate photonic effects not seen in planar tungsten films and suggest enhanced thermal emission at visible wavelengths.

2:40pm **EN+NS-ThA3 Nanowires and Nanowire Heterostructures for Thermoelectric Energy Harvesting**, ***Y. Wu***, Purdue University **INVITED**

Substantial efforts have been devoted to use nanostructured materials for thermoelectric energy harvesting and solid-state cooling in the past decade. However, the majority of the research is still limited in lab scale due to the incapability to mass-produce well-defined nanostructured materials with low yet industrial-compatible process. In addition, a lot of widely used thermoelectric materials contain toxic and expensive elements that prevent the large-scale deployment of the thermoelectric devices. In this presentation, we will discuss our research on the development of mass production of molecular scale nanostructures of chalcogenides and metal oxides, as well as their heterostructures, for the manufacture of thermoelectric generators operating at different temperature ranges. Particularly, we will talk about our approach to discover and investigate the non-toxic and abundant nanostructured materials to achieve an environmentally friendly process. Our preliminary research indicated that thermoelectric figure of merit (ZT) close to 2 can be achieved in the molecular scale nanowires of certain chalcogenide due to significantly enhanced power factor and reduced thermal conductivity as a result of quantum confinement.

3:40pm **EN+NS-ThA6 Plasmonic Polymer Solar Cells with Spectrally Tuned Au/SiO$_2$ Core/Shell Nanorods incorporated in Active Layers**, ***V. Jankovic***, *J.P. Chang*, UCLA

Octadecyl tri-methoxysilane (OTMS) functionalized Au/SiO2core/shell nanorods were incorporated into the active layers of two different polymer bulk heterojunction (BHJ) systems: a broad band gap polymer (poly(3-hexylthiophene)(P3HT):[6,6]-phenyl-C61-butyric acid methyl ester (PCB60M)) and a low band gap polymer poly{2,6-4,8-di(5-ethylhexylthienyl)benzo[1,2-b;3,4-b]dithiophene-alt-5-dibutyloctyl-3,6-bis(5-bromothiophen-2-yl) pyrrolo[3,4-c]pyrrole-1,4-dione} (PBDTT-DPP):PC60BM. The extinction peaks of the Au nanorod scattering centers was tuned to match the band edge of the two polymers by controlling their aspect ratio. For the P3HT:PC60BM system with a band edge around 700 nm, the addition of the core/shell nanorods of an aspect ratio 1:2.5 (resonant frequency peak is at around λ=650nm), resulted in 8% improvement in short circuit current (Jsc); for the low band gap polymer system PBDTT-DPP: PC60BM with band edge around 850 nm, we tuned the resonant frequency to near-infrared region by increasing the aspect ratio to 1:4 (resonant frequency peak is at around λ=800nm), the addition of the core/shell nanorods resulted in 18% improvement in short circuit current (Jsc). The Jsc enhancement was consistent with external quantum efficiency (EQE) measurements and the EQE improvement factor matched the absorption resonance spectrum of Au/SiO2 nanorods in both systems. This work will instruct us on how to utilize and manipulate plasmon resonance of metallic nanoparticles to improve device efficiency in different polymer solar cell systems.

4:00pm **EN+NS-ThA7 Optics and Photonics Research Priorities and Grand Challenges as Relating to Today's Energy Frontiers**, ***E.B. Svedberg***, The National Academies

A new report from the National Research Council of the National Academies identifies research priorities and grand challenges to fill gaps in optics and photonics, a field that has the potential to advance not only the energy field but also the economy of the United States and the world, the report provides visionary directions for future technology applications, and ensure progress in energy related research. As one of its recommendations the report recommends that the federal government develop a "National Photonics Initiative" to bring together academia, industry, and government to steer federal research and development funding and activities.

Eight particular areas of technological application are discussed in separate chapters: communications, information processing, and data storage; defense and national security; energy; health and medicine; advanced manufacturing; advanced photonic measurements and applications; strategic materials for optics; and displays. Each chapter reviews updates that have occurred since the 1998 National Research Council report Harnessing Light: Optical Science and Engineering for the 21st Century, as well as the technological opportunities that have risen from recent advances in optical science and engineering. This presentation will focus on the energy section of the report that deals not only with energy generation but also how to reduce excessive usage of energy. The report additionally recommends actions for the development and maintenance of the photonics-driven sector of the energy industry, including both near-term and long-range goals, likely participants, and responsible agents of change.

The recommended National Photonics Initiative will help manage the breadth of rapidly expanding applications of photonics technologies, allowing both governments and industry to develop coherent strategies for technology development and deployment in the energy sector. The initiative should also spearhead a collaborative effort to improve the collection and reporting of research, development, and economic data on this sector.

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