IPF on Mesoscale Science and Technology of Materials and Metamaterials
Room: 210F - Session IPF+MS-MoM

Materials for Energy Generation and Storage (8:20-10:20) & Mesoscale Phenomena in the Biosciences I (10:40-12:00)
Moderator: Alain Diebold, SUNY College of Nanoscale Science and Engineering, Carolyn Larabell, University of California, San Francisco

8:20am **IPF+MS-MoM1 Synthesis and Behavior of Nanostructures in Mesoscale Architectures**, ***SangBok Lee***, *G.W. Rubloff, E. Gillette, C. Liu,* University of Maryland, College Park, *X. Chen,* Lam Research Corporation, *J. Hu, S. Wittenberg, L. Graham,* University of Maryland, College Park, *P. Banerjee*, Washington University, St. Louis **INVITED**

As advanced nanostructured electrodes continue to push boundaries for both high power and high energy, it will become increasingly important to understand how structure on the mesoscale impacts charge transport and electrochemical reactions. Understanding the influence of structure on ionic and electronic transport behavior, as well as its influence on degradation is highly essential to design and control improved electrodes. Here, we describe the fabrication of two types of electrodes; one with electrodes constructed in the most simple cylindrical nanopores - "all-in-one nanopore battery" - and the other with electrodes in controllable 3D interconnecting pore network to propose a strategy for bridging the gap between precision, self-aligned nanostructure electrodes and disordered, high density electrodes. These architectures highlight some of the challenges of characterizing tortuosity and porosity in nanostructures, but also provides an opportunity to work with a systematically variable mesoscale electrode structure.

9:00am **IPF+MS-MoM3 Ultralight Microlattices: Defining the Limits of Lightweight Materials**, ***William Carter***, HRL Laboratories, LLC **INVITED**

Design of “materials architecture” is emerging as a new and complimentary approach to classical materials selection in engineering design. By adjusting the geometric arrangement of solid phases and voids within a material, it is possible to extend the achievable property space for lightweight materials and functional coatings. Optimal microlattice materials that can be formed in a wide range of architectures and base materials, with properties spanning from unprecedented low density and surprisingly high mechanical recovery to structural alternatives to honeycomb and foams. The starting polymer microlattice templates are created using an array of interpenetrating self-forming photopolymer waveguides from a single exposure mask. Free-standing hollow micro-lattice materials can be formed based on a wide range of high performance thin films (metals, ceramics and polymers) by coating a micro-lattice template followed by subsequent removal of the template. The process enables precise and independent control over micro-lattice architecture at all levels of structural hierarchy (~100nm up to ~10cm). This technique is also inherently scalable to low-cost high-throughput manufacturing (~10-60 second exposure), highly scalable to large sizes (m2), enabling practical design and fabrication of a wide range of lattice materials including metals, polymers and ceramics.

9:40am **IPF+MS-MoM5 "Can Opto-Electronics Provide the Motive Power for Future Vehicles?"**, ***Eli Yablonovitch***, University of California, Berkeley **INVITED**

A new scientific principle[1] has produced record-breaking solar cells. The 28.8% single-junction solar efficiency record, by Alta Devices [2], was achieved by recognizing the importance of extracting luminescent emission. This is exemplified by the mantra: “A great solar cell also needs to be a great LED”. It was essential to remove the original semiconductor substrate, which absorbed luminescence, and to replace it with a high reflectivity mirror. The solar efficiency record crept up as the rear reflectivity behind the photovoltaic film was increased, 96% reflectivity -- 97% -- 98% luminescent reflectivity;-- each produced a new world efficiency record.

In thermo-photovoltaics, high energy photons from a thermal source are converted to electricity. The question is what to do about the majority of low energy infrared photons? It was recognized that the semiconductor band-edge itself can provide excellent spectral filtering for thermophotovoltaics, efficiently reflecting the unused infrared radiation back to the heat source. Exactly those low energy photons that fail to produce an electron-hole pair, are the photons that need to be recycled.

Thus the effort to reflect band-edge luminescence in solar cells has serendipitously created the technology to reflect all infrared wavelengths, which can revolutionize thermo-photovoltaics. We have never before had such high rear reflectivity for sub-bandgap radiation, permitting step-function spectral control of the unused infrared photons for the first time. This enables conversion from heat[3] to electricity with >50% efficiency. Such a lightweight “engine” can provide power to electric cars, aerial vehicles, spacecraft, homes, and stationary power plants.

1. O. D. Miller, Eli Yablonovitch, and S. R. Kurtz, “Strong Internal and External Luminescence as Solar Cells Approach the Shockley–Queisser Limit”, IEEE J. Photovoltaics, vol. 2, pp. 303-311 (2012). DOI: 10.1109/JPHOTOV.2012.2198434

2. Kayes, B.M.; Hui Nie; Twist, R.; Spruytte, S.G.; Reinhardt, F.; Kizilyalli, I.C.; Higashi, G.S. “27.6% Conversion Efficiency, A New Record For Single-Junction Solar Cells Under 1 Sun Illumination” Proceedings of 37th IEEE Photovoltaic Specialists Conference (PVSC 2011)Pages: 4-8, DOI: 10.1109/PVSC.2011.6185831

3. The heat source can be combustion, radio-activity, or solar thermal.

10:40am **IPF+MS-MoM8 The Convergence of Synthetic Biology and Biofabrication: Guiding Biological Function at the Mesoscale**, ***William Bentley***, Fischell Department of Bioengineering, University of Maryland **INVITED**

Synthetic biology provides a means for articulating concepts into new products and products. Its toolbox is extensive, including the ability to create synthetic genomes and tailor their regulation. Early successes augmented the cell’s biosynthetic capacity and rewired its regulation, transforming our ability to produce products ranging from small molecules to fully functional therapeutic proteins at high yield. Also, the theoretical formalisms of metabolic engineering provided a basis for optimally routing its biochemical flux. With pathway analysis and optimization, cells are now engineered to produce large quantities of economically important molecules. Indeed, many “green” routes to chemical synthesis have appeared and many more are emerging. There exists great enthusiasm and investment to revolutionize several industries. Importantly, these activities have focused largely on the cell’s intracellular biochemical network and relied less on molecular cues from the immediate surroundings. Largely untapped within synthetic biology are the signaling motifs that guide cell processes and interactions among communicating populations. That is, signal molecules guide many cellular processes and these can be exploited to endow cells with “executive” function, where decision events are programmed and cells carry out tasks in addition to making products. That is, the cells themselves can be the primary “products” of synthetic biology – putting them to work in complex “noisy” environments will require tailoring their exposure to chemical cues. For example, we may eventually use engineered bacteria to fight cancer, cure diabetes, or “tune” the microbiome in our GI tracts. Biofabrication, the use of biological components and biological processes for assembly, can provide a means for tailoring hierarchical order in biological systems. We exploit the principles of biofabrication to create 3D “test tracks” where chemical cues can be spatiotemporally controlled and task-accomplishing bacteria can be appropriately designed. We will discuss the link between synthetic biology and biofabrication and highlight the potential for new discovery as well as process and product innovation.

11:20am **IPF+MS-MoM10 Using Mesoscale Modeling to Design Materials that Compute: Coupling Self-Oscillating Gels and Piezoelectric Films**, *V.V. Yashin, S.P. Levitan,* ***Anna C. Balazs***, University of Pittsburgh **INVITED**

Lightweight, deformable materials that can sense and respond to human touch and motion can be the basis of future wearable computers, where the material itself will be capable of performing computations. To facilitate the creation of "materials that compute", we draw from two emerging modalities for computation: chemical computing, which relies on reaction-diffusion mechanisms to perform operations, and oscillatory computing, which performs pattern recognition through synchronization of coupled oscillators. Chemical computing systems, however, suffer from the fact that the reacting species are coupled only locally; the coupling is limited by diffusion as the chemical waves propagate throughout the system. Additionally, oscillatory computing systems have not utilized a potentially wearable material. To address both these limitations, we develop the first model for coupling self-oscillating polymer gels to a piezoelectric (PZ) micro-electro-mechanical system (MEMS). The resulting transduction between chemo-mechanical and electrical energy creates signals that can be

propagated quickly over long distances and thus, permits remote, non-diffusively coupled oscillators to communicate and synchronize. Moreover, the oscillators can be organized into arbitrary topologies because the electrical connections lift the limitations of diffusive coupling. Using our model, we predict the synchronization behavior that can be used for computational tasks, ultimately enabling "materials that compute."

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