PCSI
Room Canyon/Sugarloaf - Session PCSI-2WeM
Material Modification and Self Assembly

Moderator: Sven Rogge, University of New South Wales, Australia

11:00am **PCSI-2WeM-31 Neuromorphic Computing with the Redox Transistor**, ***Alec Talin,*** Sandia National Laboratories **INVITED**

Efficiency bottlenecks inherent to conventional computing in executing neural algorithms have spurred the development of novel devices capable of 'in-memory' computing. Commonly known as 'memristors', a variety of device concepts including conducting bridge, vacancy filament, phase change and other types have been proposed as promising elements in artificial neural networks for executing inference and learning algorithms. In my talk, I will review the recent advances in memristor technology for neuromorphic computing and discuss strategies for addressing the most significant performance challenges, including non-linearity, high read/write currents, and endurance. As an alternative to two-terminal memristors, I will introduce the three-terminal electrochemical memory based on the redox transistor (RT) which uses a gate to tune the redox state of the channel.[1] Decoupling the 'read' and 'write' operations using a third terminal and storage of that information as a charge-compensated redox reaction in the bulk of the transistor enables high-density information storage. These properties enable low-energy operation without compromising analog performance and non-volatility. I will discuss the RT operating mechanisms using organic and inorganic materials, approaches for array integration, and prospects for achieving the device density and switching speeds necessary to make electrochemical memory competitive with established digital technology.

11:40am **PCSI-2WeM-39 Kinetically-Driven Assembly of TaS_2-SnS Heterostructures with Flexible Stacking Architectures**, ***Dennice Roberts,*** National Renewable Energy Laboratory*; D Bardgett,* University of Oregon*; B Gorman,* Colorado School of Mines*; J Perkins, A Zakutayev, S Bauers,* National Renewable Energy Laboratory

Chalcogenide heterostructures enable access to a remarkable range of materials properties by virtue of structural flexibility at the nanoscale. An interesting approach to the preparation of such heterostructures utilizes layered amorphous precursor films designed to mimic a desired superlattice heterostructure product, and has been successful in creating a wide range of metastable selenide heterostructures. An example of such tunable properties is seen in the SnSe-VSe_2 system, where changing layer sequencing can both enhance and quench charge density wave (CDW) transitions, as well as modify their onset temperatures.[1] Such CDWs in TaS_2 are hysteretic and have been proposed for phase change memory applications,[2] and so incorporating TaS_2 into superlattice structures known to enhance CDW transitions might further enhance this material towards these applications.

Previous work from our group developed a framework for preparing amorphous sulfide precursor films by RF sputtering.[3] Here we present the first crystalline sulfide heterostructures prepared using this precursor approach, composed of tunable numbers of SnS sandwiched between monolayers of TaS_2 in a superlattice. We also demonstrate the utility of combinatorial synthesis for creating precursors of several different stacking sequences in a single deposition. Structural measurements confirm smooth films with superlattice ordering as well as the presence of constituent TaS_2 and SnS layers. Superlattice architecture is confirmed by high resolution transmission electron microscopy (TEM) and EDS, resolving atomically precise sequencing of SnS and TaS_2 monolayers in the arrangement experimentally instilled into the precursors. Electronic behavior as a function of number of SnS layers is measured.

[1] R. Atkins, Chem. Mater. **26** (2014) [2] M. Yoshida, Sci. Rep. **4** (2014) [3] D. M. Roberts, JVST B **37** (2019)

11:45am **PCSI-2WeM-40 Globally Aligned Single-Wall Carbon Nanotube Films through Electrostatic Ordering**, ***Joshua Walker,*** University of Wyoming*; J Fagan, A Biacchi,* National Institute of Standards and Technology*; V Kuehl,* University of Wyoming*; T Searles,* Howard University*; A Hight Walker,* National Institute of Standards and Technology*; W Rice,* University of Wyoming

The one-dimensional nature of single-wall carbon nanotubes (SWCNTs) creates unique, anisotropic optical, electrical, and thermal characteristics. To utilize these anisotropic properties, researchers must be able to easily and reproducibly fabricate aligned SWCNT structures. To be most useful, SWCNT alignment protocols must incorporate solution-based nanotubes, as they provide the highest quality (chiral enrichment, length sorting, tube filling, etc.) nanotubes [1] which are necessary for applications.

We expanded [3] upon the slow-filtration SWCNT alignment technique [2] through automation and parallelization. Such advances not only provided increased film reproducibility and throughput, but also enabled a rapid optimization of the complex parameter space to produce the highest aligned films to date. Furthermore, this work provides researchers with a new capability to investigate the underlying physics driving alignment. We find that by controlling flow rate, flattening the meniscus, and membrane buffing, we can repeatably and automatically produce globally aligned SWCNT films. Using polarized spectroscopy, we show that high, two-dimensional nematic ordering ($S_{2D} \approx 0.9$) of SWCNTs can be achieved [3]. Experiments altering the ionic strength and membrane surface charging suggest that this ordered SWCNT phase is driven by linear charging on the membrane and inter-nanotube electrostatic interactions.

11:50am **PCSI-2WeM-41 Defining Insulating Regions on TiO_2 Thin Films by Laser Heating**, *S Ahmed, J Ritter,* ***Matt McCluskey,*** Washington State University

Optically defining conducting and insulating regions on an oxide thin film could provide a means for writing and rewriting transparent electronic circuits. Titania (TiO_2) films are straightforward to deposit and exhibit *n*-type conductivity that depends strongly on the concentration of oxygen vacancies, which act as shallow donors. Heating in a reducing atmosphere, such as vacuum or hydrogen, increases the density of oxygen donors and hence the conductivity. Conversely, heating in an oxygen atmosphere reduces the oxygen vacancy concentration and makes the sample insulating. While electrons in the rutile phase are small polarons, those in anatase TiO_2 behave as free electrons. This property makes the anatase structure preferable for applications requiring high electrical conductivity.

In the present work, 300 nm thick anatase TiO_2 films were sputtered on fused silica substrates. Heating under a rough vacuum (30 mTorr) produced conducting films with free-carrier absorption in the visible and IR. A green laser (532 nm wavelength, 1-5 W power) was then focused on regions of the sample, in the open air. Localized laser heating resulted in a 7 order-of-magnitude increase in resistance, from 10 kΩ to >100 GΩ. The heated area became transparent due to the loss of free-carrier absorption. Scanning electron microscopy (SEM) and optical transmission spectroscopy indicate that laser heating does not degrade the films. The process is reversible – conductivity is restored after annealing in vacuum again. The effect of interface heat conduction will be discussed.

11:55am **PCSI-2WeM-42 Towards Mask Free Direct Write fabrication of Micro- and Nanoscale Architectures on Different Substrates via Aqueous Ink Precursors and CVD Synthesis**, ***Irma Kuljanishvili,*** *D Alameri, D Karbach, R Dong, L Moore,* Saint Louis University*; R Divan, Y Liu,* Argonne National Laboratory

Low-dimensional materials such as 2D graphene, boron nitride or other layered van der Waals atomic crystals, WS2 or MoS2, and 1D nanowires (NWs) and nanoribbons such as ZnO, and other semiconducting materials, have drawn significant attention in the past decade due to their nanoscale geometry and unique physical, chemical, optical properties as These low dimensional materials when assembled/interfaced in vertical or lateral arrangements often lead to the largely enhanced properties, and new functionalities. While the preparation of layered architectures usually involves multi-step fabrication processes it also relies predominately on a mask assisted lithographic techniques.

Here we present a mask-free controlled selective preparation of 1D and 2D nanostructures of MoS2, WS2 and ZnO in the variety of geometric assemblies by employing parallel direct- write patterning (DWP) of aqueous ink precursors on substrates and devices at predefined locations. In a two-step process (1st patterning and 2nd growth) our unconventional fabrication approach enables simple and flexible production of hetero-structures and other architectures based on "mix and match" principle in precisely controlled fashion. Location specific synthesis of materials also provides access to as-grown interfaces and rapid testing of materials quality, crystallinity and chemical composition can be easily confirmed by several non-destructive surface probe tools such as Raman Spectroscopy, PL, AFM, XRD etc. Our 'bottom-up' approach offers simple and flexible route to rapid testing of prototype nano-architectures and platforms, via multiplexing and the ease of probing device interfaces their viability and robustness and the potential for further development of specific targeted applications.

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+ Author for correspondence:irma.kuljanishvili@slu.edu

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