2022 IEEE Dayton Section-NAECON Workshops

**19 July 2022**

**Air Force Institute of Technology (AFIT) Kenney Hall, B642, Wright-Patterson Air Force Base (WPAFB), OH (In-Person) plus YouTube (Virtual)**

The IEEE Dayton Section, original promoter of the National Aerospace & Electronics Conference (NAECON) invites you to participate in this year’s one day event exploring novel research and contributions to next generation aerospace technologies. This one-day event will be conducted in person at AFIT’s Kenney Hall and virtually via AFIT’s YouTube Channel.

**Event Details**

**19 July – Tutorials – 0830-1630 ET**

<https://www.youtube.com/watch?v=6pd_8ny70so>

**8:45 AM-9:00 AM Introductory Remarks, Dr. Charles Cerny**

**Workshop on Silicon Carbide (SiC) Power Devices (organized by Professor Philip Feng, University of Florida, and John Boeckel, Air Force Research Laboratory (AFRL)**

**9:00 AM-9:45 AM Invited Talk, “Establishing a World-class Silicon Carbide Substrate Manufacturing Capability”, Dr. John Blevins, AFRL**

**9:45 AM-10:30 AM Invited Talk, “SiC and Epitaxial Graphene: Materials Properties and Applications for the US Navy”, Dr. Rachel Myers-Ward, NRL (Virtual)**

**10:30 AM- 10:45 AM Break**

**10:45 AM- 11:30 AM Invited Talk, “Silicon Carbide MEMS/NEMS and Photonic Devices: Fundamentals, Progress, and Emerging Applications}, Dr. Philip Feng, University of Florida**

**11:30 AM-12:30 PM Lunch (Free for IEEE members- Need registration through V-Tools)**

**Workshop on Memristors and Neuromorphic Computing (Organized by Dr. Sabyasachi Ganguli, AFRL, and Guru Subramanyam, University of Dayton)**

**12:30 PM- 1:15 PM Invited Talk, “Neuromorphic computing enabled by diffusive memristors”, Professor Joshua Yang, University of Southern California (Virtual)**

**1:15 PM- 2:00 PM Invited Talk, “CMOS-integrated Non-volatile Resistive Memory for Neuromorphic and In-memory Computing Applications”, Professor Nathaniel Cady, SUNY Polytechnic (Virtual)**

**2:00 PM- 2:45 PM** **Invited Talk, “Nano scale PCM for neuromorphic computing”, Professor Ethan Ahn, University of Texas at San Antonio**

**2:45 PM- 3:00 PM Break**

**3:00 PM-3:45 PM Invited Talk, “Two- and Three-Terminals Resistive Random Access Memories Memristive Devices for Storage and Neuromorphic Applications”, Professor Rashmi Jha, University of Cincinnati**

**3:45 PM-4:30 PM Invited Talk, “****Multiphysics Model for Prediction of I-V Characteristics of Oxide-Based Memristor Devices in an 1T1R Configuration”, Dr. Sangwook Sihn, University of Dayton Research Institute and AFRL Materials and Manufacturing Directorate**

**Registration**

Event registration is accessed via IEEE vTools:  [IEEE Dayton Section/NAECON 2022 - Tutorials - AFIT Kenney Hall & YouTube - 19 Jul : vTools Events](https://events.vtools.ieee.org/m/319545). This allows for accounting of registrants attending in person vice those participating virtually. For those attending in person who require base access please contact Dr. Charles Cerny (dr.c.c@ieee.org) or Maj Timothy Wolfe (Timothy.Wolfe@afit.edu). Parking will be available on Ascani and 10th Streets Parking Lots.

**Establishing a World Class Silicon Carbide Substrate Manufacturing Capability**

J. D. Blevins

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***Abstract***: Silicon carbide (SiC) semiconductor substrates provide the foundation for revolutionary improvements in the cost, size, weight, and performance of a broad range of military and commercial radio frequency (RF) and power switching devices.Due to the lack of a viable, native gallium nitride (GaN) substrate, semi-insulating (SI) SiC substrates are required for fabrication of AlGaN/GaN High Electron Mobility Transistors (HEMTs) due to their near lattice-match to GaN, superior thermal conductivity and commercial availability. GaN HEMTs have emerged as the RF technology of choice due to its superior power*-*frequency product over any competing solid-state RF power amplifier technology. Similarly, semi-conducting (N+) SiC substrates are required for fabrication of high voltage Schottky Diodes and Metal Oxide Semiconductor Field Effect Transistor (MOSFET) power switching devices**.** System electrical power generation, distribution and control electronics are becoming increasingly critical as expanded mission profiles demand more power for propulsion, radar, DEW, EW and EA. Critical to this realization is the availability of affordable, high quality, large diameter SI and N+ SiC substrates for production of these semiconductors.

Assured access to SiC substrate supply has been prohibitively difficult due to the inability of companies to secure the necessary crystal growth IP, scientific expertise and long term financial commitment. Production of SiC substrates requires a high temperature (~2200 °C) sublimation process that was fraught with perceived insurmountable technical challenges associated with micropipes, doping, polytype control, diameter expansion and crystalline defects. Overcoming these barriers has been the focus of AFRL for the past 20 years to commercialize new sources of SiC substrate technology. AFRL’s sustained investment and industrial cost share has led to the creation of a world class manufacturer of SiC substrates. Presently, II-VI is the second largest producer of SiC substrates in the world behind Cree-Wolfspeed. During the course of these efforts, II-VI successfully scaled their crystal growth, boule fabrication and substrate polishing processes from <50 mm to 200 mm diameter [1].

[1] J. D. Blevins, “Development of a World Class Silicon Carbide Substrate Manufacturing Capability”, *IEEE Transactions on Semiconductor Manufacturing*, vol. **33**, no. 4, pp. 539-545, 2020.

**Mr. John Blevins** is a Principal Materials Engineer with the Air Force Research Laboratories (AFRL) Materials and Manufacturing Directorate where he directs the manufacturing maturation of a broad scope of advanced semiconductor technology aimed at meeting evolving AF radar, electronic warfare and communication system requirements. Mr. Blevins has over 30-years’ experience in the development and manufacturing of compound semiconductor materials and has served as Air Force Program Manager for numerous DARPA electronics development initiatives. Mr. Blevins possesses a B.S. Materials Engineering (1987) Wright State University and a M.S. Materials Engineering (1991) from University of Dayton.

**SiC and Epitaxial Graphene: Materials Properties and Applications
for the US Navy**

Rachael Myers-Ward

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**Abstract:**

Silicon carbide (SiC) has been a material of interest for high-temperature, high-voltage and high-power switching device applications. The SiC substrates are also used to epitaxially grow graphene, which has been recognized for its exceptional physical, electronic and optical properties. This seminar will briefly discuss some of the initial SiC research conducted for high power applications in the Wide and Ultrawide Bandgap Materials Section at the Naval Research Laboratory. Additionally, a more in-depth report will be given on epitaxial graphene grown via Si sublimation from SiC substrates as the material of choice for sensor development, including underwater and sulfur sensors. Finally, the use of graphene as a release layer for remote epitaxial films to impact power electronics and quantum science applications will be presented.

**Bio:**

Dr. Rachael Myers-Ward is an electrical engineer in the Power and Advanced Materials Branch/ Wide and Ultrawide Bandgap Materials Section at the U.S. Naval Research Laboratory. She received a Ph.D. in Electrical Engineering and B.S. and M.S. degrees in Chemical Engineering from the University of South Florida. Her research interests include epitaxial growth of SiC via chemical vapor deposition for high power/high voltage device applications and quantum sciences, methods to reduce extended and point defects in SiC epitaxial layers, and synthesis of epitaxial graphene for sensor applications. Dr. Myers-Ward has organized 10 conference symposia and is on the AVS Governance Committee. Her scientific contributions have led to 135+ publications with an H-index of 39, one book chapter, and 12 patents.

**Silicon Carbide MEMS/NEMS and Photonic Devices:
Fundamentals, Progress, and Emerging Applications**

Philip Feng

Professor, Department of Electrical & Computer Engineering, University of Florida, Gainesville, FL, USA

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***Abstract***: Silicon carbide (SiC), an advanced polymorphic material of great technological importance, possesses very attractive characteristics including wide bandgap, transparency from visible to near infrared, large refractive index, excellent thermal conductivity, very high elastic modulus and remarkable mechanical hardness and chemical inertness. These attributes make SiC interesting and promising for a number of emerging and critical applications, ranging from high-temperature electronics to sensors and transducers enabled by micro/nanoelectromechanical systems (MEMS/NEMS), to photonics and quantum information processing. In this talk, I will first present a very brief review on some of the key results from a decade of collaborative research efforts on exploring SiC nanostructures for enabling new information processing functions. I will introduce the fundamentals of NEMS enabled by SiC, including nanofabrication and signal transduction in SiC nanodevices. I will then focus on the development of SiC NEMS, photonic, and optomechanical devices for sensing, signal processing, and computing, including in unconventional and harsh environments. These devices technologies include SiC NEMS resonators with high quality (*Q*) factors, self-sustained feedback oscillators, SiC NEMS switches and logic gates that can operate at high temperatures (up to 500°C), SiC nanophotonic and optomechanical resonators, highly sensitive optical detection of multimode SiC resonators, optically transduced SiC micromechanical resonators operating in liquids and biosolutions for sensing and manipulating micro/nanoparticles and cancer cells, *etc*. Finally, I shall discuss and present today’s open challenges, opportunities, and future perspectives of deepening fundamental and engineering studies of SiC materials and devices for emerging applications.

**Short Bio:**

**Philip Feng** is a Professor in Electrical & Computer Engineering (ECE) at University of Florida. His research is primarily focused on emerging semiconductor devices and integrated micro/nanosystems (particularly MEMS/NEMS), especially those based on advanced semiconductors (such as SiC, AlN, Ga2O3), 2D materials and their van der Waals heterostructures, quantum devices, and their heterogeneous integration with mainstream technologies. Feng received his Ph.D. in Electrical Engineering from Caltech. His research and educational activities have been recognized by several awards include the NAE Grainger Foundation Frontiers of Engineering Award, the NSF CAREER Award, the Presidential Early Career Award for Scientists and Engineers (PECASE), and several Best Paper Awards (with his students) at IEEE and other international conferences. He has served for IEEE IEDM/MEMS/Transducers/IFCS, and was a chair for IEEE MEMS 2021.

**Neuromorphic computing enabled by diffusive memristors**

J. Joshua Yang

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**Abstract:**

CMOS technology has been the mainstream hardware technology for the development of ubiquitous information technology so far. In the era of ‘big data’ and ‘Internet of Things’ nowadays, the traditional computing architecture based on CMOS hardware has become increasingly inefficient to support Artificial Intelligence (AI) and Machine Learning (ML), which necessitates some emerging technologies, such as memristive technology. Memristive devices have become a promising candidate to enable bio-inspired computing with much improved efficiency and throughput. Such computing can be implemented on a Resistive Neural Network with memristive synapses and neurons or a Capacitive Neural Network with memcapacitive synapses and neurons. I will first briefly introduce the traditional drift memristors for deep learning accelerators with supervised online learning. I will then focus on diffusive memristors and discuss how to use such dynamical devices to enable neuromorphic computing related applications, including timing selector, fully memristive neural networks with unsupervised learning, and memcapacitive neural networks capable of associative learning and efficient dot product computing.

****J. Joshua Yang is a professor of the Department of Electrical and Computer Engineering at the University of Southern California. He was a professor of the ECE department at the University of Massachusetts Amherst between 2015 and 2020. He spent about 8 years at HP Labs between 2007 and 2015, leading the emerging devices team for memory and computing. His current research interest is Post-CMOS hardware for neuromorphic computing, machine learning and artificial intelligence, where he published several pioneering papers and holds 118 granted and about 60 pending US Patents. He is the Founder Chair of the IEEE Neuromorphic Computing Technical Committee, a recipient of the Powell Faculty Research Award and a recipient of UMass distinguished faculty lecturer and UMass Chancellor's Medal, the highest honor of UMass. He was named as a Spotlight Scholar of UMass Amherst in 2017.He is a Clarivate™ Highly Cited Researcher in the field of Cross-Field and serves on the Advisory Boards of a number of prime international journals and conferences. Dr. Yang is also an IEEE fellow for his contributions in resistive switching materials and devices for nonvolatile memory and neuromorphic computing.

**CMOS-integrated Non-volatile Resistive Memory for Neuromorphic and In-memory Computing Applications**

Prof. Nathaniel Cady

SUNY Polytechnic Institute

Non-volatile resistive memory devices offer the potential for low power, highly scalable implementation of non-von Neumann computing architectures. Over the past 10 years, my research group has focused on fabrication and integration strategies for CMOS-compatible, non-volatile memory devices (aka: memristors). Recently we have been exploring the potential of these devices to act as neuronal synapses in neural networks and for in-memory computing applications. One challenge with introducting novel memory devices is integration with traditional CMOS processing and manufacturing. In this talk I will describe the unique technological aspects of resistive random access memory (RRAM) based non-volatile memory devices, our integration approach using 65nm CMOS in the Albany Nanotech 300mm foundry, as well as demonstration of this novel hardware for neuromorphic and in-memory computing applications.

Prof. Cady obtained his BA and Ph.D. from Cornell University in Ithaca, NY. He is currently an Empire Innovation Professor of Nanobioscience in the College of Nanoscale Science & Engineering at SUNY Polytechnic Institute, and is the Interim Vice President of Research. Prof. Cady has active research interests in the development of novel biosensor technologies and biology-inspired nanoelectronics, including hardware for neuromorphic computing. He has published over 150 peer reviewed scientific papers and is an inventor on 11 patents. His research has been supported by the NIH, NSF, AFRL, ARL, DOE, ONR, SRC, as well as multiple industry partners.

**Nanoscale PCM for Neuromorphic Computing**

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**Abstract**

PCM (phase-change memory) is an important class of data storage, operating based on the Joule heating-induced reversible switching of chalcogenide alloys. Recently, hardware implementation of deep learning has made a remarkable stride with the emerging non-volatile memory technology, and PCM is among the most promising candidates to accelerate this technological trend. In this talk, state-of-the-art research on PCM-based neuromorphic computing will be reviewed along with the promises and challenges as compared with other memristor technologies based on transition metal oxides, ferroelectrics, and magnets. Additionally, how best the nanoscale PCM device can be implemented for neuromorphic computing will be discussed in the context of down-scaling and energy efficiency.

**Speaker Bio**

Dr. Ahn is currently an Assistant Professor of Electrical Engineering at the University of Texas at San Antonio. Previously, he served as a Sr. Process Engineer at Apple, Inc. He received his Ph.D. at Stanford University in 2015. He is the author of over 75 peer-reviewed research papers in nanoelectronics. Dr. Ahn has been the recipient of numerous awards and honors, including the AFRL ML-RCP award (2022), the AFOSR grant in Quantum Electronic Solids (2019), and the NSF Eager grant (2019). He is currently serving as the concentration chair for Electronic Materials and Devices at UTSA. Dr. Ahn has also served as the technical committee member of the IEEE Electron Devices Society (EDS) for optoelectronic devices. His research interest includes nanoscale materials and devices for emerging computing paradigm.

**Two- and Three-Terminals Resistive Random Access Memories Memristive Devices for Storage and Neuromorphic Applications**

Rashmi Jha

University of Cincinnati

**Abstract:** Resistive Random Access Memory (RRAM) Memristive Devices have gathered tremendous research interests for high density data storage and neuromorphic applications. This talk will cover some of the challenges with two-terminals (2T) RRAMs and propose strategies to integrate gate in RRAMs to result in three-terminals (3T) RRAM devices. The talk will present experimental data on 3T RRAMs and discuss applications development in the domain of neuromorphic computing where gate-control can provide opportunities for implementing advanced training algorithms.

**Biography:** Dr. Rashmi Jha is a Professor in Electrical Engineering and Computer Science (EECS) Department at the University of Cincinnati, Cincinnati, USA. She worked as a Process Integration Engineer for Advanced CMOS technologies at IBM Semiconductor Research and Development Center, East Fishkill, NY, USA prior to moving to the academia. She finished her Ph.D. and M.S. in Electrical Engineering from North Carolina State University, Raleigh, North Carolina, USA in 2006 and 2003, respectively, and B.Tech. in Electrical Engineering from Indian Institute of Technology (IIT) Kharagpur, India in 2000. She has been granted 13 US patents and has authored/co-authored several publications. She has been a recipient of Summer Faculty Fellowship Award from AFOSR, USA in 2021 & 2017, CAREER Award from the National Science Foundation (NSF), USA in 2013, IBM Faculty Award in 2012, and IBM Invention Achievement Award in 2007. She is the director of Microelectronics and Integrated Computing Systems with Neuro-centric Devices (MIND) laboratory at the University of Cincinnati. Her current research interests lie in the areas of Advanced CMOS and Beyond CMOS Devices, Artificial Intelligence, Neuromorphic and Brain-Inspired SoC, Cybersecurity with emphasis on Microelectronics, and Neuroelectronics.

# Multiphysics Model for Prediction of I-V Characteristics of Oxide-Based Memristor Devices in an 1T1R Configuration

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**Abstract:** A non-volatile switching memory platform has recently attracted great interest as it provides a unique potential to enable the realization of human brain like neuromorphic computing efficiency. Memristors are novel nanoscale non-volatile resistive memories with a high resistance ratio above 1000 between high resistance state (ON state) and low resistance state (OFF state), good temperature tolerance, long-term durability, high tunability with nanosecond pulses, which are very attractive for the neuromorphic computing. In order to better understand the material processing, microstructure and property relationship of switching mechanisms in the memristor devices, computational methodologies and tools were developed to predict I-V characteristics of oxide-based memristor devices in an 1T1R configuration subject to externally biased voltages. A multiphysics model based on coupled partial differential equations for electrodynamic and thermal transport phenomena were solved for the high- and low-resistance states upon formation, growth and destruction of a conducting filament (SET state), and those of an insulating gap (RESET state), which represent the migration of oxygen vacancy in an oxide exchange layer. Two discrete models for four modules (ON, OFF, SET and RESET) were implemented in a commercial multiphysics finite element software, COMSOL. Various model parameters including the material properties for two oxide materials (TaOx and HfOx) were determined from a series of sensitivity study. Model predictions were compared with experimental data measured with the two oxides. Once validated, the model could further be used to identify critical parameters (material type, morphology and doping in the metal oxides as well as surrounding electrodes) affecting the device performance and durability of the memristor devices during long-term cyclic operations.

**Dr. Sangwook Sihn** is a Senior Research Engineer at the University of Dayton Research Institute working in the Air Force Research Laboratory as an on-site contractor for more than 20 years in the field of analysis and development of advanced materials and structures. He has conducted researches on the mechanical, thermal, electronic and electromagnetic analyses of advanced materials including, but not limited to, fiber-reinforced polymeric matrix composites and nanocomposites, carbon nanotubes, graphene and graphites, foams and phase change materials to be used for efficient mechanical, thermal, electronic and electromagnetic applications. He has developed various multiscale computational models and softwares to be used for the analysis and design of multifunctional advanced materials and their structures. He has contributed to 5 book chapters, 40 journal publications, and more than 100 conference presentations and online tutorials.