

6-2017

Agenda: Second International Workshop on Thin Films for Electronics, Electro-Optics, Energy and Sensors (TFE3S)

University of Dayton Research Institute

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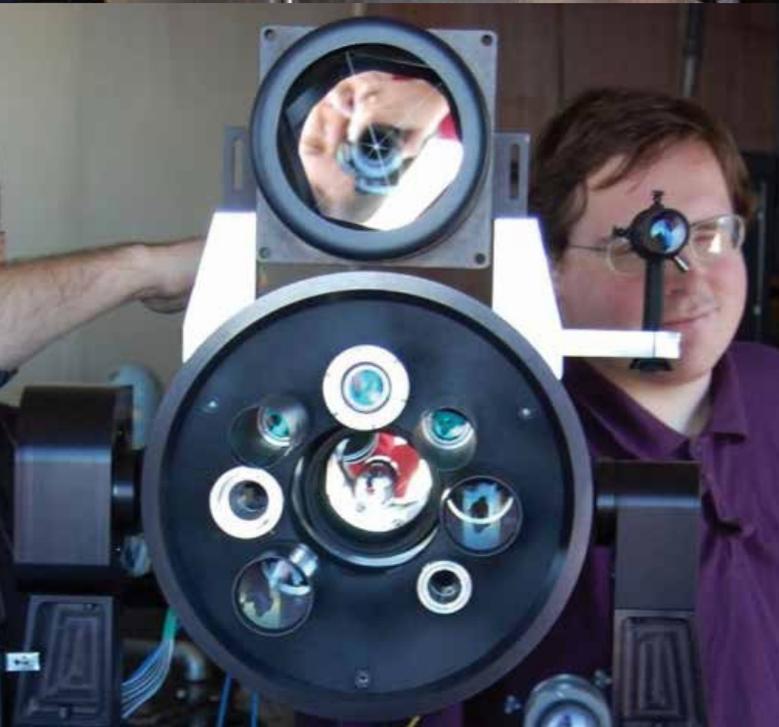
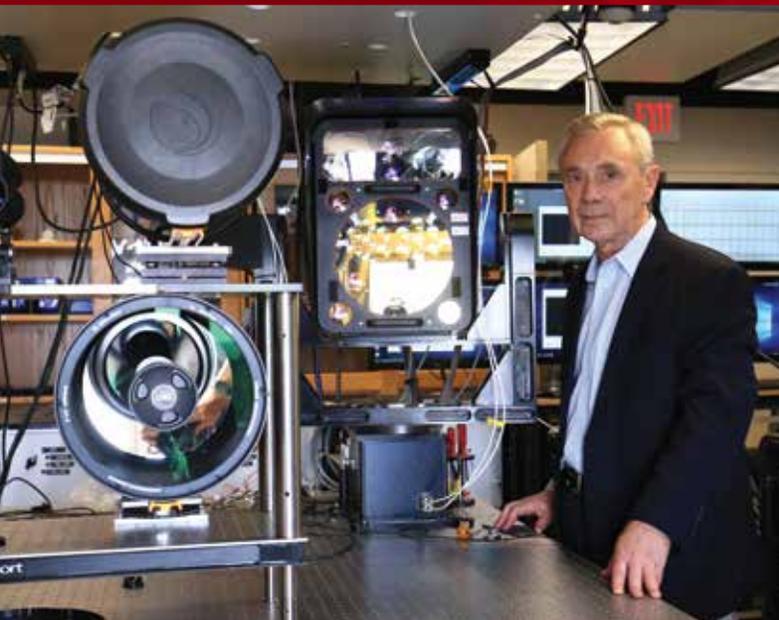
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AGENDA

SECOND INTERNATIONAL WORKSHOP ON THIN FILMS FOR ELECTRONICS, ELECTRO- OPTICS, ENERGY AND SENSORS (TFE3S)



June 25–27, 2017

**University of Dayton
Research Institute
Dayton, Ohio, USA**



International Workshop on Thin Films for Electronics, Electro-Optics, Energy and Sensors

go.udayton.edu/thinfilmworkshop



Dayton, OH, USA
June 25–27, 2017



Organized by

The University of Dayton and University of Dayton Research Institute

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Vision and Topics

University of Dayton's Center of Excellence for Thin Film Research and Surface Engineering (CETRASE) is delighted to organize its second international workshop at the University of Dayton's Research Institute (UDRI) campus in Dayton, Ohio, USA. The purpose of the new workshop is to exchange technical knowledge and boost technical and educational collaboration activities within the thin film research community through our CETRASE and the UDRI.

Topics include, but are not limited to:

1. Thin films for energy harvesting and energy storage
2. Thin film microelectronics
3. Multifunctional oxide thin films
4. Organic and biological thin films
5. Flexible and printable electronics
6. Phase-change materials, and other thin film sensor materials
7. Thin film meta-materials and optical thin films

Full Manuscript Submittal Instructions

The program committee invites all invited and contributing authors to submit a full length manuscript for the proceedings of the TFE3S workshop, to be published by SPIE.

Full Manuscript Submission Deadline: July 31, 2017

Full manuscripts of 6-8 pages in length can be submitted for review. Figures should be clear enough with axis markings and legends that are legible. The technical program committee and session chairs for technical merit will review manuscripts. A sample manuscript will be available for participants.

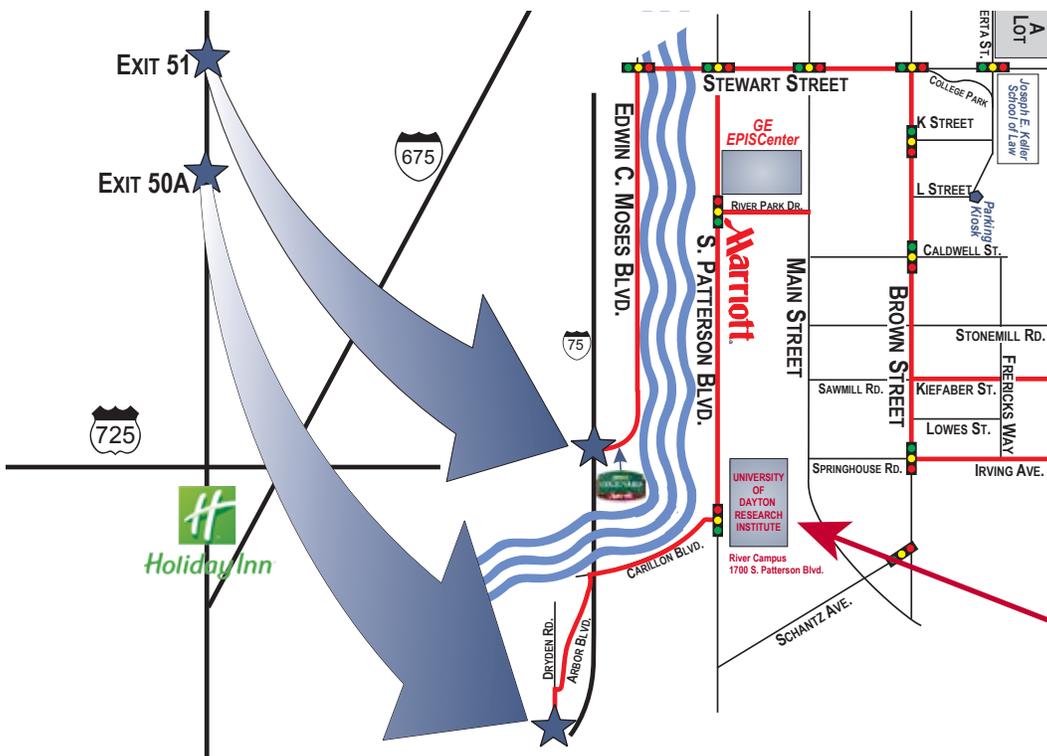
Manuscript submission will be through the SPIE website: spie.org/x14101.xml.

The symposium code is TFE3S17 for the manuscript submission.

TFE3S17 Agenda

All attendees welcome to the reception on June 25th, Sunday 6-8 PM,
Carillon Brewing Company, 1000 Carillon Blvd, Dayton, OH 45409

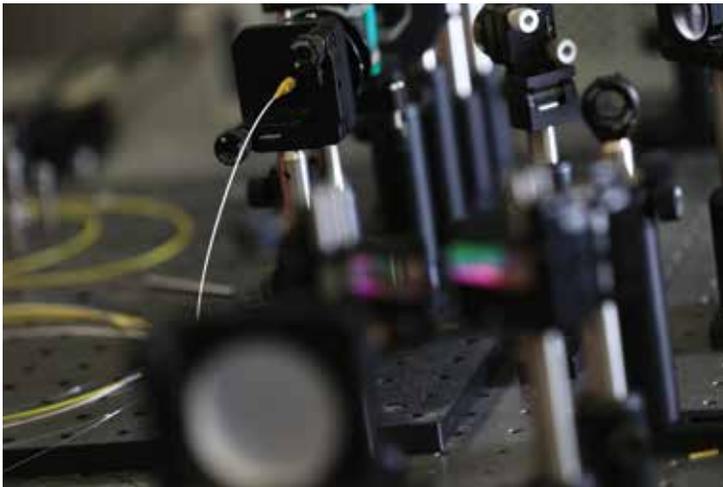
Workshop held at the University of Dayton's River Campus,
1700 S. Patterson Blvd, Dayton, Ohio



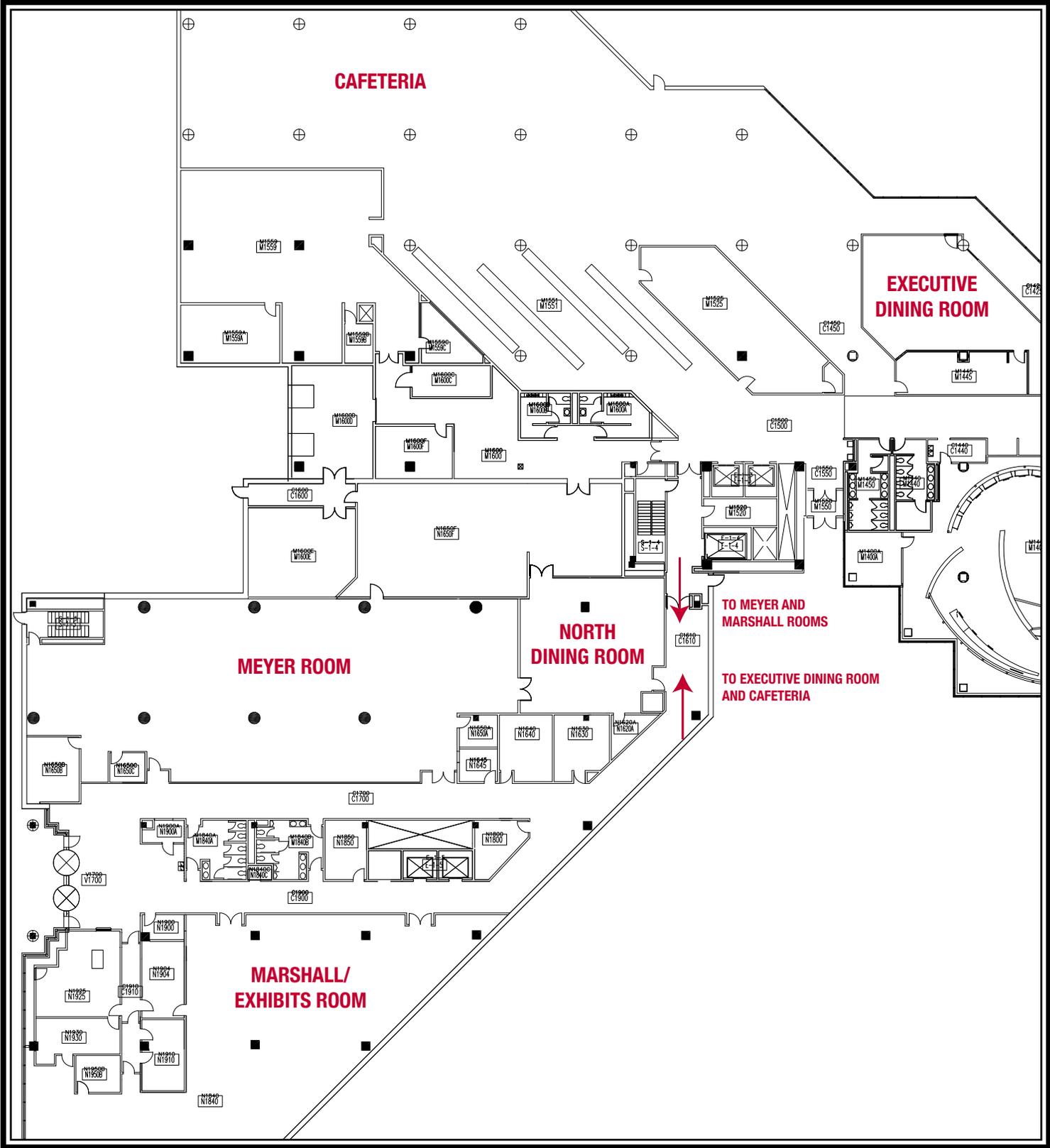
Please park in the
North End Lot — no
pass required during
the conference.

Agenda At-A-Glance

	Day 1 (June 26)		Day 2 (June 27)	
8:30–10:15 a.m.	Opening Ceremony+ Plenary Speakers (Marshall Room)		Plenary Speakers (Marshall Room)	
	Coffee Break (15 min)		Coffee Break (15 min)	
10:30 a.m.–12 p.m.	Session 1A (Marshall)	Session 2A (Exec Dining)	Session 5A (Marshall)	Session 6 (Exec Dining)
1:15.–2:45 p.m.	Session 1B (Marshall)	Session 2B (Exec Dining)	Session 5B (Marshall)	Session 7 (Exec Dining)
	Coffee Break (15 min)		3:15–4 p.m. Coffee and Refreshments (Marshall Room)	
3–4:30 p.m.	Session 3 (Marshall)	Session 4 (Exec Dining)		
4:30–5:45 p.m.	Poster Session (Marshall Room)			
	5:30–6 p.m. Cash Bar			
6–8 p.m.	Banquet Dinner (Cafeteria)			



Room Location Map



Day 1 (Morning) — June 26, 2017

Time	Event	Location
8 a.m.–4 p.m.	Registration	Lobby

OPENING CEREMONY & PLENARY I

8:30–8:45 a.m. Opening Remarks, Dr. John Leland, VP for Research, University of Dayton • Marshall Room

▶ **(8:45–9:30 a.m.)** Plenary Talk II Burhan Bayraktaroglu, AFRL Sensors Directorate • Marshall Room

Title: ZnO Thin Film Transistors (Paper ID TFE17-22)

Abstract: ZnO is a multi-functional semiconductor with applications in electronic, optical and mechanical systems. It has been used in electrical surge protector applications for many years before it was realized that it can also be used for transistors. ZnO has 2 basic properties that make it highly desirable for unique electronic applications. First, it has a wide bandgap, which makes it suitable for high voltage and high temperature applications. Second, it can be grown on non-crystalline substrates, which makes it compatible with thin film applications. ZnO thin films are spontaneously ordered and close-packed nanocrystals with electronic properties very similar to single crystals. Low resistance non-alloyed contacts and low surface state densities allow the fabrication of thin film transistors with almost ideal DC characteristics and microwave performance.

Bio: *Burhan Bayraktaroglu received B.Sc. and Ph.D. degrees, both in electrical engineering, from the University of Newcastle-Upon-Tyne, Newcastle-Upon-Tyne, UK in 1974 and 1978. He has been involved in the development of compound semiconductor devices including GaAs HBTs and GaN HEMTs for microwave applications while working at Texas Instruments, Westinghouse and Northrop Grumman over a 20 year period. He was the VP of technology at Anadigics and chief technology officer at Nitronex developing new technologies for mobile telecommunications. He held academic positions at North Carolina State University and Wright State University as a research scientist. He is currently the principal electronics engineer at the Air Force Research Laboratory, Sensors Directorate responsible for the development of high performance nanocrystalline ZnO thin film electronics for sensor circuit applications. He has over 175 technical publications and 45 U.S. patents in microelectronics and nanotechnology.*

NOTES:

Title: Atomic Layer Semiconductors for Emerging 2D Devices and Systems (Paper ID TFE17-25)

Abstract: Atomically thin crystals isolated from new classes of layered bulk materials are emerging to enable two-dimensional (2D) nanostructures with unusual electronic, optical, mechanical and thermal properties. While graphene has been the forerunner and hallmark of 2D crystals, newly emerged compound and single-element 2D semiconductors offer attractive attributes beyond those of graphene's (e.g., including sizeable and tunable bandgaps covering a wide spectrum with technological importance). In this presentation, I will describe my research group's latest efforts on the design, fabrication, and characterization of new 2D nanodevices based on atomic layer semiconducting crystals, with functions in electronic, mechanical and optical domains. We focus on exploring and exploiting the multiphysical coupling effects in single- and few-layer semiconducting transition metal dichalcogenides (TMDCs) and black phosphorus, to engineer novel signal transduction schemes in these ultrathin nanostructures, and to develop new electronic, optoelectronic devices, and ultralow-power 2D nanoelectromechanical systems (NEMS) [1-6] that can operate in vacuum, air and even in liquid. I will show the demonstrations of highly tunable 2D NEMS and vibrating-channel transistors using single-layer and few-layer TMDCs. I will describe spatially resolved mode shapes and Brownian motion detection and mapping in these atomic layer multimode nanoresonators at room temperature. I will then present tunable black phosphorous devices that exploit the crystal's unique and strong in-plane anisotropy. Finally, I will discuss perspectives of 2D devices and systems in physical sensing, IoT and other applications.

References:

- [1] Wang, Jia, Feng, et al., "Resolving and Tuning Mechanical Anisotropy in Black Phosphorus via Nanomechanical Multimode Resonance Spectromicroscopy," *Nano Lett.* 16, 5394-5400 (2016).
- [2] Jia, Yang, Feng, et al., "Large-Scale Arrays of Single-and Few-Layer MoS₂ Nanomechanical Resonators," *Nanoscale* 8, 10677-10685 (2016).
- [3] Yang, Islam, Feng, "Electromechanical Coupling & Design Considerations in Single-Layer MoS₂ Suspended-Channel Transistors and Resonators," *Nanoscale* 7, 19921-29 (2015).
- [4] Wang, Jia, Feng, et al., "Black Phosphorus Nanoelectromechanical Resonators...", *Nanoscale* 7, 877-884 (2015).
- [5] Wang, Lee, Feng, "Spatial Mapping of Multimode Brownian Motions...", *Nature Communications* 5, 5158 (2014).
- [6] Lee, Wang, Feng, et al., "High Frequency MoS₂ Nanomechanical Resonators," *ACS Nano* 7, 6086-6091 (2013).

Bio: Philip Feng is currently an associate professor in electrical engineering at Case School of Engineering, Case Western Reserve University (CWRU). His group's research is primarily focused on emerging nanoscale devices and integrated microsystems. He received his Ph.D. at Caltech in 2007. His recent awards include a National Science Foundation CAREER Award, 4 Best Paper Awards (with his advisees, at IEEE NEMS 2013, IEEE Int. Freq. Control Symp. 2014, and American Vacuum Society Int. Symp. 2014, 2016), and a university-wide T. Keith Glennan Fellowship. He is also the recipient of the Case School of Engineering Graduate Teaching Award (2014) and the Case School of Engineering Research Award (2015). He was one of the 81 young engineers selected to participate in the National Academy of Engineering (NAE) 2013 U.S. Frontier of Engineering (USFOE) Symposium. Subsequently, he was selected to receive the NAE Grainger Foundation Frontiers of Engineering (FOE) Award in 2014. He was nominated for the John S. Diekhoff Award for distinguished graduate student mentoring and for the Bruce Jackson Award for excellent undergraduate mentoring. He has served on the Technical Program Committees (TPC) and as Track/Session Chairs for IEEE IEDM, IEEE MEMS, Transducers, IEEE IFCS, IEEE SENSORS, IEEE NANO, and other conferences.

10:15-10:30 a.m. COFFEE BREAK

NOTES:

Morning Sessions

Time	Session	Title	Location
10:30 a.m.–12:00 p.m.	Session 1A	Thin Films for Energy Storage and Energy Harvesting	Marshall Room

Chairs: Dr. Dionne Hernandez-Lugo, NASA Glenn Research Center, and Dr. Jitendra Kumar, University of Dayton Research Institute

▶ (10:30–11 a.m.) Dr. Yu Zhu, University of Akron (Invited)

Title: Advanced Silicon Composite Anodes for Lithium Ion Batteries (Paper ID TFE17-12)

Abstract: The state-of-the-art lithium ion batteries (LIBs) do not have sufficient specific energy for emerging applications such as electrical vehicles. One route to increase the energy density of LIBs is the use of a silicon-based anode. Unlike conventional graphite anodes, which only have capacity of one lithium ion per six carbon atoms (372 mA-h/g), silicon-based anodes have a theoretical capacity of 4.4 lithium ions per silicon atom (4,200 mA-h/g). These results indicate that the Si anode offers great promise for achieving high specific energy LIBs. However, silicon-based anodes have yet to achieve widespread adoption or commercialization due to the large volume change that occurs upon lithiation/delithiation, resulting in severe electrode pulverization and degradation. In this work, novel polymer binder materials mitigating the volume expansion of the Si particles were developed. These binder materials were applied in half-cell, and the batteries exhibited excellent cyclability. The battery exhibited area capacity over 1.5 mAh/cm² and negligible degradation in the first 100 cycles.

Bio: Dr. Yu Zhu obtained his Ph.D. in physical chemistry at the University of Cologne, Germany, in 2007. After his post-doctoral training in Professor James Tour's lab at Rice University, Dr. Zhu joined the Department of Polymer Science at The University of Akron as an assistant professor in 2012. Dr Zhu's research areas comprise synthesis and assembly of carbon nanomaterials and polymers and the use of those novel materials in energy storage devices, nano-electronics and organic electronics.

NOTES:

▶ (11–11:30 a.m.) Dr. Vijay Singh, University of Kentucky (Invited)

Title: Nanowire Device Configurations for Enhanced Performance in CdTe Based Solar Cells (Paper ID TFE17-13)

Abstract: Embedded CdS nanowires were used as window layers in CdS-CdTe solar cell devices. Enhanced transmission through the window layer, reduced junction area by 68 percent, and the resulting increased quantum efficiency was demonstrated. However, in spite of the reduced junction area, the open circuit voltage (V_{oc}) values were still below 850 mV. This was attributed to the presence of excessively large interface state density at the CdS-CdTe heterojunction. So, further reduction of interface state population was sought through a homojunction device design that uses the nanowire n-CdTe/p-CdTe configuration. In the window layer of this device, embedded n-CdS nanowires are replaced by embedded n-CdTe nanowires.

n-CdTe nanowires were grown inside the pores of anodized aluminum oxide by galvanostatic electrodeposition from a non-aqueous bath. Schottky diodes were formed on these nanowires and their materials and electro-optical characteristics were measured. Spectral transmission measurements showed that the overall transmittance of CdTe nanowires was higher than that of embedded CdS nanowires, which was in turn higher than that of the planar CdS film used in the traditional CdS-CdTe solar cell devices. Current–voltage measurements yielded values of reverse saturation current density (J_0) and diode ideality factor (n) to be $0.6 \mu\text{A}/\text{cm}^2$ and 4.5, respectively. Analysis of the capacitance-voltage (C-V) measurements revealed that the carrier concentration (N_d) in the n-CdTe nanowires is in the 10^{16} cm^{-3} range.

Bio: *Dr. Vijay Singh is Earl Parker Robinson Chair Professor in the Department of Electrical and Computer Engineering at the University of Kentucky, in Lexington, KY. He began his research career in solar cells at the Institute of Energy Conversion, University of Delaware in 1974. He joined the microelectronics industry in 1976 first as a research engineer and later as section head and manager of materials and device research for Photon Power Inc., El Paso, Texas. In 1983, he joined the faculty of the Department of Electrical and Computer Engineering at the University of Texas at El Paso, where he served as the director of the Electronic Devices Laboratory (1983-1999), Schellenger Chair Professor (1990-1999), and associate dean for engineering (1995-1999). In 2000, he joined University of Kentucky in Lexington, KY, as professor and Earl Parker Robinson Chair in Engineering. There, he has served as department chair (2000-2007), director of the Center for Nano-Scale Science and Engineering (2001-2015) and as director of the Electronic Devices Research Laboratory (2000-Present). He is the author of more than 150 journal and technical articles, patents and book chapters. His research interests are in the areas of solar cells, nanotechnology, sensors and electroluminescent displays.*

▶ (11:30 a.m.–12 p.m.) Professor Je-Hyeong Bahk, University of Cincinnati (Invited)

Title: High Performance Nanostructured Thin Films and Composites for Efficient Thermoelectric Energy Harvesting (Paper ID TFE17-15)

Abstract: Energy consumption in our society is rapidly increasing, but nearly 60 percent of the generated energy is wasted in the form of heat. Thermoelectric energy conversion has recently attracted great attention as a viable technology for direct conversion of waste heat to electricity and thus enhance energy efficiency. A new emerging application for thermoelectrics is harvesting energy from human body-heat on the skin using wearable thermoelectric generators. In this talk, we briefly review the recent advances in the development of nanostructured thermoelectric materials for energy harvesting and discuss the nanoscale transport physics behind the recent enhancement in these materials. We will present our recent development of nanostructured thermoelectric materials including solution-processed nanowire-based heterostructure nanocomposites and Bi/Te core/shell nanowires. Finally, we will focus on our newly-developed three-dimensional graphene:polymer nanocomposite films developed at the Nanoworld facilities at Univ. Cincinnati for thermoelectric applications. Detailed growth and material characterization of the 3D graphene:polymer composites will be discussed and analyzed for further material optimization.

Bio: *Dr. Je-Hyeong Bahk is currently assistant professor jointly at the Department of Mechanical and Materials Engineering and the Department of Electrical Engineering and Computing Systems, the University of Cincinnati, Ohio, USA. Dr. Bahk received his B.S. and M.S. in electrical engineering from Seoul National University, South Korea, and Ph.D in electrical engineering from the University of California, Santa Barbara, in 2010. Before joining UC, he worked as a postdoctoral researcher at Brick Nanotechnology Center, Purdue University.*

NOTES:

Chairs: Professor Marc Cahay, University of Cincinnati, and Dr. Terry Murray, CETRASE, University of Dayton

▶ (10:30–11 a.m.) Dr. David Look, Semiconductor Research Institute, Wright State University (Invited)

Title: Electrical and Optical Characterization of Transparent Conductive Oxide Films (Paper ID TFE17-26)

Abstract: Transparent conductive oxide thin films are very important in the electronics and optoelectronics industries; thus, accurate, quantitative characterization of their electrical and optical properties is important. For uniform bulk slabs of material, Hall-effect (HE) measurements yield exact (model-free) values of mobility (μ_H) and concentration (n) of the free carriers; similarly, reflectance/transmittance (R/T) measurements in uniform material gave exact values of absorption and reflectance coefficients, or equivalently, the real and imaginary components of the index of refraction. However, thin films typically do not stand alone but require a substrate to give them structural integrity; thus, in principle, a *two-layer* analysis of the electrical and optical data is necessary. Even so, *single-layer* HE and R/T analyses may still be sufficient if the substrate is semi-insulating and if the incident light is mostly absorbed in the thin film. Here we will discuss what can be learned in two, thin-film materials presently of high interest to the electronics community: Ga-doped ZnO and Si-doped Ga₂O₃, both grown by pulsed laser deposition (PLD) at the AFRL. In each case, near-record carrier concentrations have been achieved, permitting analysis of plasmonic properties. In particular, we can compare μ_H and n , from HE measurements, with μ_{opt} and n_{opt} , based on a Drude analysis of R/T measurements. Among practical results, we show that a concentration $n = 2.2 \times 10^{20} \text{ cm}^{-3}$ can be achieved in PLD-grown Si-doped Ga₂O₃. Theoretical fitting of the temperature-dependent Hall mobility then yield a donor concentration $N_D = 3.5 \times 10^{20} \text{ cm}^{-3}$ and an acceptor concentration $N_A = 1.3 \times 10^{20} \text{ cm}^{-3}$. From SIMS measurements, $[\text{Si}] = 4.1 \times 10^{20} \text{ cm}^{-3}$, giving an excellent doping efficiency $N_D/[\text{Si}] = 85$ percent. The identity of the acceptors is unknown, but may involve Ga vacancies.

Bio: Dr. David C. Look is senior research physicist and director of the Semiconductor Research Center at Wright State University, Dayton, Ohio. He has carried out extensive electrical, optical, and magnetic resonance studies of many compound semiconductors, including CdS, GaAs, GaN, ZnO, ScN, and Ga₂O₃. He wrote the book *Electrical Characterization of GaAs Materials and Devices*, Wiley, 1989, and has published over 500 journal articles, leading to an h-index of 78. Dr. Look also assists in the organization of the biannual International Workshops on ZnO and Related Materials, and the annual Conference on Oxide-based Materials and Devices (SPIE). He is a fellow of the American Physical Society (1981) and received the William Fowler award from the American Physical Society (2014).

▶ (11-11:30 a.m.) Dr. Bruce Claflin, Air Force Research Lab Sensors Directorate (Invited)

Title: Group-IV Semiconductor Alloy Thin Films Containing Tin: Synthesis and Applications (Paper ID TFE17-27)

Abstract: Group-IV semiconductor materials play a central role in modern society: Si-based complementary-metal-oxide-semiconductor (CMOS) devices form the foundation of digital logic circuits in personal computers and SiGe-based heterojunction bipolar transistor (HBT) devices are widely used for telecommunications and radio-frequency (rf) applications. The one drawback to these materials is that both Si and SiGe alloys have an indirect bandgap that makes them unsuitable for optoelectronic applications. However, it has been recently demonstrated that the addition of Sn to form GeSn or SiGeSn alloys can produce thin films with a direct bandgap. This work will review recent developments in the synthesis and characterization of group-IV alloys containing Sn and will discuss their potential use in a number of optoelectronic applications.

Bio: Dr. Claflin is a semiconductor physicist with expertise in photonic and electronic materials synthesis and characterization. He has more than twenty years experience conducting university, industry and government research on advanced Si CMOS technologies as well as 2-d materials, wide bandgap II-VI and III-V semiconductors. His current interests focus on growth and characterization of group-IV semiconductor alloys. Dr. Claflin has published more than seventy technical publications and three book chapters.

NOTES:

▶ (11:30 a.m.–12 p.m.) Professor Savas Kaya, Ohio University (Invited)

Title: Low Cost Multiscale Patterning Via Photo-Initiated PMMA for Thin Film Devices (Paper ID TFE17-18)

Abstract: Polymethyl methacrylate (PMMA) is a versatile high resolution electron-beam and X-ray resist, which has been enhanced with a photo-cross-linker to perform as a standard negative photo-resist. It has also been utilized as a DUV resist without the use of a development, termed dry lithography. Both of these techniques enable high resolution, cost-effective patterning for non-traditional devices such as printed electronics, micro-optics, waveguides, micro-fluidics, polymer casting, and so on. The newly gained dry and negative-tone lithographic capability does not impact PMMA's desired properties as a high-quality electron-beam resist, granting a significant amount of processing versatility. In this work, we will demonstrate practical examples of thin-film structures using PMMA-based patterning techniques.

Bio: Savas Kaya received his Ph.D. from Imperial College of Science, Technology and Medicine, London, in 1998, for his work on strained Si quantum wells on vicinal substrates, following the MPhil degree in 1994 from the University of Cambridge. He was a postdoctoral researcher at the University of Glasgow between 1998-2001, carrying out research in transport and scaling in Si/SiGe MOSFETs, and fluctuation phenomena in nano MOSFETs. He is a senior member of the IEEE and is currently a professor at the Russ College of Engineering at Ohio University, Athens. His other interests include transport theory, device modeling and process integration, nanofabrication, nanostructures and nanosensors.

12–1:15 P.M. LUNCH (EXECUTIVE DINING ROOM)

▶ (12:30–1:15 p.m.) Lunch time Keynote, Professor Tarek Taha

Title: Low SWAP Architectures for Deep Learning and Cognitive Systems (Paper ID TFE17-28)

Abstract: With power consumption becoming a critical processor design issue, neuromorphic processors are becoming very popular for low power, high throughput computing. There are several options for neuromorphic processors, these include: implementation technology (such as digital CMOS vs. mixed signal memristor) and neural capability (such as number of cores or on-chip learning). This talk will explore the different design options we have been exploring for neuromorphic processors. We have designed both digital and memristor based analog multicore neuromorphic processors (both with and without on-chip learning capabilities). We have shown that neuromorphic processors can be up several orders more energy efficient than multicore RISC processors or GPGPUs. Additionally, the talk will discuss applications we have examined for neuromorphic processors, including the IBM TrueNorth processor and memristive processors we have designed. We have explored several applications including cognitive decision making, cybersecurity (network intrusion detection) and image processing. Finally, the talk will describe how to our work on implementing specialized memristor based circuits for convolution neural networks, deep learning and anomaly detection.

Bio: Tarek Taha is an associate professor of electrical and computer engineering at the University of Dayton. His specializations are in neuromorphic computing and high performance computing. He is working on designing neuromorphic processors and evaluating their applications. He works closely with the Air Force Research Lab, the National Security Agency, and has several projects on the topic of neuromorphic processors, including the development of autonomous agents for these platforms (in particular, the IBM TrueNorth processor), neuromorphic architectures for cybersecurity, and memristor fabrication and circuit design. He has spent several summers at the NSA and AFRL. Dr. Taha received his B.S.E.E., M.S.E.E., and Ph.D. in electrical engineering, all from the Georgia Institute of Technology. He is a recipient of the NSF CAREER Award.

NOTES:

Afternoon Sessions

Time	Session	Title	Location
1:15–2:45 p.m.	Session 1B	Thin Films for Energy Storage and Energy Harvesting	Marshall Room

Chairs: Dr. Dionne Hernandez-Lugo, NASA Glenn Research Center, and Dr. Jitendra Kumar, University of Dayton Research Institute

► (1:15–1:45 p.m.) Professor Vesselin Shanov, University of Cincinnati (Invited)

Title: CVD Synthesis, Characterization and Applications of Three-Dimensional (3D) Graphene for Advanced Applications (Paper ID TFE17-29)

Abstract: Chemical Vapor Deposition (CVD) of 2-dimensional (2D) graphene has been extensively studied. Less attention has been paid on fabrication and characterization of 3D graphene structures. Here, we report synthesis of a novel 3D graphene body called graphene pellet (GP) and make use of it by fabricating graphene paper. Graphene pellet was synthesized by CVD, using nickel particles with defined grain size. This porous metal body served as a catalyst and produced 3D graphene when exposed to a gas mixture of methane, hydrogen and argon at 1000°C. The obtained graphene pellet was processed by acid for removing the remaining nickel catalyst. This procedure yielded almost 100 percent pure 3D graphene structure, which was characterized by SEM, ICP, Raman and 4 probe electrical measurements. The obtained 3D graphene was converted into a thin graphene paper by pressing, which exhibits a breaking stress of 22 ± 1.4 MPa and electrical conductivity of up to 1136 ± 32 S cm⁻¹. The manufactured graphene paper preserves the 3D structure of its building blocks. Paper with thickness of 50 µm revealed 60 dB electromagnetic interference (EMI) shielding effectiveness, which makes it a promising shielding material [1]. Another application of the 3D graphene that will be illustrated is fabrication of electrodes for supercapacitors [2]. Data related to the performance of such an energy storage device will be also presented. Two of the fabricated coin cell supercapacitors can easily power a light emitting diode. Performance data of such an energy storage device will be also presented. Two of the fabricated coin cell supercapacitors can power an LED. We will report also about Micro Super Capacitor (MSC) that is very flexible and achieved high power density of 14.4 mW cm⁻² and energy density of 0.38 µWh cm⁻² [3].

References:

- [1] L. Zhang, N. Alvarez, M. Zhang, M. Haase, R. Malik, D. Mast, V. Shanov, "Preparation and Characterization of Graphene Paper for Electromagnetic Interference Shielding," *Carbon*, 82, pp. 353-359, (2014).
- [2] L. Zhang, D. DeArmond, N. Alvarez, Daoli Zhao, T. Wang, G. Hou, R. Malik, W. Heineman, V. Shanov, "Beyond Graphene Foam, a New Form of Three-Dimensional Graphene for Supercapacitor Electrode," *J. Materials Chemistry A*, 4, pp. 1876-1886, DOI: 10.1039/C5TA10031C (2016).
- [3] L. Zhang, D. Armond, N. Alvarez, R. Malik, N. Oslin, Colin McConnell, P. Adusei, V. Shanov, "Flexible Micro-Supercapacitor based on Graphene with Three Dimensional Structure," *Small*, DOI: 10.1002/smll.201603114, pp. 1603114 (2017).

Bio: Dr. Vesselin Shanov is a professor with the chemical engineering program at the School of Biomedical, Chemical and Environmental Engineering, and the co-founder and co-director of the teaching and research facility NANOWORLD Lab at the University of Cincinnati. He received his M.S. in electronic materials from the University of Chemical Technology and Metallurgy, Sofia, Bulgaria. Dr. Shanov completed his Ph.D. in solid state chemistry at the University of Chemical Technology and Metallurgy, Sofia, Bulgaria, and at the University of Regensburg, Germany. He has international academic and industrial experience in research and development related to technologies and facilities for processing of advanced materials. His recent research focuses on synthesis, characterization, processing and application of nanostructured materials with emphasis on carbon nanotubes, graphene, as well as on biodegradable Mg for medical implants. Applications of his research are in the areas of electronics, aerospace and nanomedicine. Dr. Shanov has more than 300 scientific publications, including 16 patents, 12 provisional patents and 5 books, cited in about 2,400 different references. He has received several prestigious awards, among them the German Academic Foundation (DAAD) Award and the Fulbright Award for Research and Teaching in USA.

NOTES:

► (1:45–2:15 p.m.) Dr. Paul Matter, pH Matter LLC (Invited)

Title: Three-Dimensional Current Collector for Energy Storage Applications (Paper ID TFE17-30)

Abstract: Thin-film properties of materials can vary significantly from bulk material properties. For example, previous research has shown that thin-film silicon-anodes in lithium ion batteries have excellent stability and high specific capacity. Unfortunately, thin films do not provide sufficient mass loading to store enough energy for a useful device. pH Matter, LLC is developing a three-dimensional current collection approach to enable thick-film electrodes with high areal capacity and similar specific capacity and stability to the thin-film counterparts. The three-dimensional current collector allows thin films to be effectively packaged into a small geometric area. This talk will review approaches being taken to demonstrate high capacity silicon anodes using three-dimensional current collectors and future directions for the technology, including fuel cells and other battery electrodes.

Bio: *Dr. Paul Matter is the president and co-founder of pH Matter, LLC. The company specializes in the development and commercialization of material-related products for advanced energy and aerospace applications, with particular expertise in carbon-based materials for electrodes. Since being founded in 2011, the company has delivered its products and technologies to customers including NASA, the U.S. Air Force, the U.S. Army, and both its U.S.-based and international business partners. Dr. Matter received his B.S. in chemical engineering from the Ohio State University in 2001, graduating summa cum laude with distinction. He also received his Ph.D. from Ohio State in chemical engineering in 2006. Dr. Matter worked previously as chemical systems engineer at Nexceris (previously NexTech Materials). Overall, Dr. Matter's career work has resulted in a book chapter, 20 peer reviewed journal articles, three issued patents, six patents pending and numerous conference presentations.*

► (2:15–2:45 p.m.) Dr. Shailendra K. Jha, CECRI, India (Invited)

Title: Three-Dimensional Electrode Architectures and Its Application in Energy Storage and Sensing Systems (Paper ID TFE17-31)

Abstract: Electrochemistry is at the forefront of some exciting electrochemical sensing, energy conversion and storage applications, such as dopamine, glucose, hydrogen peroxide, fuel cells, supercapacitors, batteries and a few types of solar cells. With the advent of relatively inexpensive and versatile electrochemical instruments, and a wide range of applications, it is now possible to design three-dimensional micro/nanostructure interfaces and acquire a variety of electrochemical data with relative ease. Common fabrication techniques typically require multiple and complex processing steps to create 3D electrode architectures. So here an ultrathin Ni/Ni(OH)₂ hybrid electrode has been synthesized using a controlled reverse pulse modulated electrochemical approach and demonstrated as an advanced pseudocapacitor material having a remarkable specific capacitance and excellent cycling performance. [1] Most of the energy storage electrode materials experience large volume changes caused by concentration changes within the host particles during charging and discharging. Electrode failure, in the form of fracture or decrepitation, can occur as a result of repeated volume changes. A stress assisted diffusion model for thin film and alloy electrode materials for lithium batteries has been developed. The present study provides insight for designing and evaluating the electrodes of lithium-ion batteries by taking the interface effects into account. [2] A facile and reproducible *in situ* electrodeposition method has been used for the tuning the architecture of graphene-CuNi micro- and nanostructure without the usage of any templates, surfactants or stabilizers. The effects of electrodeposition potential and electrolytes concentration on the formation of different architectures such as dendrites, pyramid and sugar cube along with time-dependent morphological evolution are investigated in detail. As-synthesized graphene-CuNi micro- and nanostructures were further tested for electrooxidation of glucose in alkaline medium. [3]

References:

- [1] Raj, R. P.; Mohan, S.; Jha, S. K. *Chem. Commun.*, 52 (2016) 1930.
- [2] Selvi, G. T.; Jha, S. K. Manuscript under preparation (Unpublished Results).
- [3] Kumar, M. K.; Jha, N. S.; Jha, S. K. (Manuscript under review).

Bio: *Dr. Shailendra K. Jha joined as a scientist in CSIR-Central Electrochemical Research Institute, Karaikudi, Tamil Nadu, in January, 2012, and contributed in many areas of electrochemical science. For example, he has contributed to fundamental electrochemical science by developing supercapacitor through a novel controlled reverse pulse modulated electrochemical approach, fuel cell, non-enzymatic hydrogen peroxide, glucose and dopamine electrochemical sensors and published in various peer reviewed international journals of high repute and impact factors. He did his master's degree in chemistry from the Department of Chemistry at the University of Delhi, a foremost university department in the country; he carried out his Ph.D. work there with Professor Rama Kant, an eminent theoretical electrochemist.*

Session	Title	Location
Session 2B	Thin Film Microelectronics	Executive Dining Room

Chairs: Professor Marc Cahay, University of Cincinnati, and Dr. Terry Murray, CETRASE, University of Dayton

► (1:15–1:45 p.m.) Dr. Vamsy Chodavarapu, CETRASE, University of Dayton (Invited)

Title: CloudMEMS: Cybermanufacturing of Micro-Electro-Mechanical Systems (TFE17-32)

Abstract: Micro-Electro-Mechanical Systems (MEMS) have revolutionized our modern lifestyle and have emerged as a key enabler for many of our present consumer electronics and industrial utilities, including smartphones, tablets, wearables, internet-of-things, automobiles, aircrafts and toys. Many crucial industrial automation and defense applications are now possible, only because of the various sensing, actuation and signal processing functions performed by MEMS, such as small unmanned aerial vehicles, deep water oil drilling and smart munition. The new era of “More-than-Moore” has begun in the semiconductor industry, which is undergoing a tectonic shift towards creation of value added products and services rather than simply focusing on incrementally advancing the state-of-the-art in integrated circuit technology (i.e., simply More-Moore), with MEMS expected to play an increasingly important role in the new era. Both design and development of MEMS demand highly sophisticated Computer Aided Design (CAD) tools, elaborate microfabrication facilities and extensive packaging infrastructure. Such excessive requirements are: (1) Limiting our ability to foster the next technological revolution and (2) Restraining creative thinking and aspirations of today’s “Do-It-Yourself” generation. In the above light, new design and development platforms that are ubiquitously accessible, low-cost, expandable, modular, and interactive for MEMS development and manufacturing, are in high demand while strengthening our cyberinfrastructure. To this end, we have undertaken the first step by creating the Microsystem Idea-to-Innovation service (i.e., MI2 service, <http://misquare.org/mi-square-service/>) at the University of Dayton (UD) by bringing together some of the world’s leading pure-play MEMS foundries that offer standardized processes to provide fabrication access at a low cost to entrepreneurs and innovators (e.g., small and startup companies).

Bio: *Dr. Vamsy Chodavarapu is an associate professor in electrical and computer engineering at the University of Dayton, OH. His research is based on scientific inquiry and engineering execution in the areas of CMOS sensor microsystems, RF/analog circuits, neuro-/biomedical- prosthetics and wearables, bio-/neuro-/RF- MEMS, biological/chemical sensing and nano-/bio- materials. He has extensive experience in the commercialization and licensing of sensor and instrumentation technologies. He has published more than 100 research articles in peer-reviewed journals and conferences. He is listed on 10 approved/ pending U.S. patents. He has co-founded 2 companies, Nxtsens Microsystems Inc., Montreal, QC, Canada, and Prixarc, LLC, Dayton, OH, USA. Nxtsens Microsystems was ranked as one of the top 60 emerging silicon companies in the world in 2016 by EE Times. He is a senior member of IEEE and SPIE. His entire list of publications can be seen at <http://misquare.org/publications/>*

NOTES:

▶ (1:45–2:15 p.m.) Dr. Andrew Green, Air Force Research Lab, Sensors Directorate (Invited)

Title: Ga₂O₃ Based MOSFETs (Paper ID TFE17-24)

Abstract: Beta-phase gallium oxide (β -Ga₂O₃) is the most promising wide bandgap semiconductor since the maturation of GaN and SiC. The main advantages of β -Ga₂O₃ are its wide bandgap (~4.8 eV) and native substrate availability, which can be synthesized by melt-growth technology with a wide variation in dopant type and range. These main technical merits position β -Ga₂O₃ extremely well for low-defect density homoepitaxial growth of β -Ga₂O₃ on cost-effective, large-area substrates for high-voltage applications. β -Ga₂O₃ has an estimated critical field strength (EC) of ~8 MV/cm leading to a Baliga's Figure of Merit (~EC³) for power-switching far surpassing GaN and SiC. Green et al. have already reported a measured EC = 3.8 MV/cm for a lateral β -Ga₂O₃ MOSFET, which surpasses theoretical bulk EC for GaN and SiC. Further, while the saturation velocity (v_{sat}) of β -Ga₂O₃ is not well-known, it would need only be ~1/3 of GaN to have a near-equal Johnson Figure of Merit (~v_{sat}•EC) for high-frequency power operation. Here, we document our progression of β -Ga₂O₃ device development towards monolithically integrated high-voltage devices.

Bio: Andrew Green received a B.S. and Ph.D. in chemistry from Ohio University in 2010 and 2013 respectively. His research involved studying nanoscale heat transfer from optically excited gold nanoparticles. In 2014, he began working at the Air Force Research Laboratory at Wright Patterson Air Force Base. He is involved in the device development of multiple material technologies. He works on monolithic microwave integrated circuit technology in AlGaIn/GaN high electron mobility transistors. He also is involved in monolithic heterogeneous integration of compound III-V semiconductors with substrate agnostic materials such as IGZO or ZnO. Finally, he performs device research for the new power electronics material β -Ga₂O₃.

▶ (2:15–2:45 p.m.) Dr. Parag Banerjee, St Louis University (Invited)

Title: Atomic Layer Deposition from Surface Science to Surface Engineering (Paper ID TFE17-33)

Abstract: Atomic layer deposition (ALD) is a process that continues to challenge our understanding of surface reactions with new chemistries, while successfully enabling applications where atomically precise layers significantly improve performance of devices such as transistors, capacitors, solar cells and batteries. In this talk, I will first describe the work our group has conducted understanding the role of configurational entropy of adsorbed molecules in determining surface reactions in ALD that lead to growth of films one monolayer at a time. I will then describe two case studies where we show ALD provides the ideal process platform to control film nanomorphology, thickness and composition at the atomic level. These case studies will highlight 1) novel use of second-harmonics to study metal-induced gap states at the Au-Al₂O₃ interface and 2) development of atomically engineered, transparent conducting zinc oxides with completely quenched green-band photoluminescence.

Bio: Professor Parag Banerjee joined Washington University in St. Louis as faculty in the Mechanical Engineering and Materials Science Department in July 2011. Prior to this appointment, he obtained his Ph.D. under the supervision of Professor Gary Rubloff at the University of Maryland, College Park in materials science & engineering. From 2000 to 2006, he was an R&D process engineer at Micron Technology, Inc, working on atomic layer deposition (ALD) of high-k dielectrics. Professor Banerjee's current work uses ALD as a key technological platform to understand and control charge transport across material interfaces with applications in photodetection and photon harvesting. His work is supported by DoE, NSF and ARO.

2:45–3 p.m. COFFEE BREAK

NOTES:

Time	Session	Title	Location
3-4:30 p.m.	Session 3	Multi-functional Oxides and Multiferroics	Executive Dining Room

Chairs: Chonglin Chen, University of Texas, San Antonio, USA, and Nian Sun, Northeastern University

► (3-3:30 p.m.) Dr. Brandon Howe, AFRL Materials and Manufacturing Directorate

Title: Next-Generation Electronic Materials Processing Tools Newly Developed at AFRL (Paper ID TFE17-36)

Abstract: Next-generation warfighter electronics rely on the development of truly disruptive and robust electronic and optical materials in order to enable game-changing advancements in RF/microwave performance and frequency-agility. The community is extremely materials limited and the major scientific challenge lies in the creation of novel materials and heterostructures with exceptionally high crystalline quality in order to unlock and explore unique and interesting properties. In order to accomplish this, one must create novel processing schemes in order to access never-before-achieved synthesis space, thus unlocking the ability to grow materials with properties far beyond conventional materials. Recently, at the Materials and Manufacturing Directorate at AFRL, we have built up a state-of-the-art PVD epitaxy suite capable of quickly scanning through an enlarged processing space in order to rapidly assess and identify novel materials with enhanced physical properties towards AF application. This talk will focus on the buildup and characterization of both a fully automated UHV pulsed laser epitaxy tool for the growth of high quality ferromagnetic oxides and oxide heterostructures as well as a truly one-of-a-kind and fully automated multifunctional epitaxial growth system (MEGS) capable of applying magnetic fields during both magnetron sputter epitaxy as well as pulsed laser deposition and creating complex metal/metal nitride/oxide heterostructures never before achieved. I will show how these systems are already creating exceptionally high quality transition metal nitride for resilient plasmonics (as TiN and ZrN mirror the properties of gold and silver) and novel magnetic oxides with record magnetic and microwave performance. The nitrides grown by sputtering demonstrate properties among the best reported as well as reveal incredibly low roughness values and evidence of step-flow growth, while our novel AlNiZnFerrite material demonstrates record high magnetostriction while mitigating prohibitively large losses (microwave damping).

Bio: *Dr. Brandon Howe is a materials engineer at Air Force Research Lab's Materials and Manufacturing Directorate, Nanoelectronic Materials Branch. He was recruited to AFRL under the SMART (Science Mathematics, and Research for Transformation) Scholar program in 2006. He graduated in 2011 from University of Illinois at Urbana-Champaign, after studying under the guidance of Profs. Ivan Petrov and Joe Greene. During his time there, he won several awards in the area of thin films and vacuum technology. He has spent the last few years renovating, redesigning and constructing a UHV PLD and magnetron sputter epitaxy suite and is now leading the epitaxial magnetoelectrics effort for next-generation tunable RF/microwave components.*

NOTES:

▶ (3.30–4 p.m.) Professor Yan Zhuang, Wright State University

Title: Magnetic Thin Films for Si RF Technology (Paper ID TFE17-37)

Abstract: Advances in today's electronics, in large extent, benefit from miniaturization or "scaling-down" of Si-based integrate circuit (IC) technology. It is foreseen that continuously scaling will face significant challenges. One major bottleneck among others is caused by the limited material set in the standard Si technology. In this presentation, opportunities of introducing magnetic thin films into Si RFIC will be addressed: (1) Integrated radio-frequency (RF) passive components have become indispensable elements of monolithic RF systems. The integrated passive components on the chip, however, occupy a large fraction of the total chip area, such as inductors. One way to cope with this issue is to increase the inductance per area by raising the permeability with the insertion of a ferromagnetic (FM) core into the inductor coil. Such concept will not only compact RF inductors, but also components that are well established in hybrid RF systems, such as isolators, circulators, non-reciprocal phase shifters and tunable components can be adopted for RF-IC technology. (2) Skin effect universally exists in natural conductive materials with non-zero magnetic permeability and finite electrical conductivity. The fact, that current flows within the skin depth at frequency f ($\delta \propto 1/\sqrt{f\mu\sigma}$), inevitably leads to power dissipation dominated at radio and microwave frequency. Materials containing both high conductivity and eliminated skin effects do not exist in the natural world. An artificial layered metamaterial (ARLYM) was introduced. Due to its zero permeability, the skin effects were effectively suppressed in a wide frequency range.

Bio: *Dr. Yan Zhuang, received his Ph.D. in physics from Johannes Kepler University, Austria, 2000. Dr. Yan Zhuang has authored or co-authored 61 peer-reviewed papers in scientific journals. The group he previously led at Delft University of Technology in the Netherlands was dedicated to the development of monolithic integration of novel magnetic and ferroelectric materials for RF integrated circuit (IC) applications. He demonstrated the first on-chip CMOS technology compatible magnetic thin film inductor, and the first on-chip electric current-controlled tunable passives, by using MEMS technology. They also developed nano-granular NiFe thin film, showing record-high ferromagnetic resonance frequency, which is particularly welcome for RF IC applications. Recently, Dr. Zhuang reported success for the first time in making low-loss magnetic/metal superlattice for RF and microwave IC application. The proposed material exhibited remarkably higher conductivity than any naturally existent. Since joining Wright State University in 2008, Dr. Zhuang has established a research group focusing on integration of micro-/nano- components and RF/microwave systems. The group works on RF and biomedical sensor systems achieved by multifunctional RF integration or by the integration of RF electronics and components with other physical domains. The group has been developing a graphene based bio- and chemical-sensors, and successfully demonstrated a graphene based sensor showing extremely high sensitivity up to sub-ppb (part per billion) on detection of ammonia for the high hazard index toxic industrial material and dimethyl methylphosphonate for the stimulant of the nerve agent sarin.*

▶ (4–4:30 p.m.) Professor Andrew Sarangan, CETRASE, University of Dayton

Title: Electrical and Optical Properties of Vanadium Dioxide Phase Change Thin Films Produced by Ion-Assisted Reactive Evaporation (Paper ID TFE17-38)

Abstract: In this talk, the properties of VO₂ phase switching films produced by oxygen ion-assisted deposition (IAD) using reactive electron beam evaporation will be reviewed. The insulator-to-metal phase transition in these films have important applications in thermal detection, electrical switching, optical switching and reconfigurable photonic circuitry. The VO₂ films produced from IAD exhibit a lower transition temperature of around 55°C compared to other methods, and a resistivity ratio of 10³ to 10⁴. The reduced transition temperature has been attributed to the lower intrinsic film stress from the IAD process. Additionally, the films produced using IAD do not require a separate annealing step. Optical properties of these films have been measured in the visible and infrared spectrum.

Bio: *Dr. Andrew Sarangan is a professor in the Department of Electro-Optics and Photonics at the University of Dayton, Ohio. He received his B.A.Sc. and Ph.D. degrees from the University of Waterloo in Canada in 1991 and 1997 respectively. His current research areas are in infrared photodetector technologies, optical thin films, nanofabrication, nano-structured thin films and computational electromagnetics. At Dayton, he created a comprehensive nano-fabrication laboratory for thin films, lithography and semiconductor processing, as a single-PI effort from externally funded research. His research has been sponsored by the National Science Foundation, various agencies of the Department of Defense and the Air Force Research Laboratory.*

NOTES:

Time	Session	Title	Location
3–4:30 p.m.	Session 4	Organic and Biological Thin films	Marshall Room

Chair: Professor Wen Li, Michigan State University, and Professor Karolyn Hansen, CETRASE, University of Dayton

▶ (3:15–3:45 p.m.) Dr. Wen Li, Michigan State University (Invited)

Title: Hybrid Diamond-Polymer Thin Film Electrodes for Neurotransmitter Sensing (Paper ID TFE17-34)

Abstract: Polycrystalline diamond (PCD) has a unique combination of electrochemical, optical and biological properties, which makes it outperform other carbon electrode materials for electrochemical sensing and neural interfacing applications. This talk will review our recent progress in the development of flexible boron-doped PCD (BDD) thin film electrodes for applications in neurotransmitter sensing. In particular, we have developed a novel fabrication method of transferring macro/microscale, all diamond structures from a diamond growth substrate (silicon) onto a flexible Parylene-C substrate, enabling the wafer-scale fabrication of all diamond-on-polymer devices. The unique design of Parylene anchors greatly enhanced the bonding strength between BDD and Parylene-C. This fabrication method is compatible with conventional micromachining technologies and can be adapted in the fabrication of flexible BDD devices for large areas or multiple targeted areas of interest. The comparative study demonstrates that our flexible BDD sensor has a much wider potential window and smaller double layer capacitance than traditional gold electrodes, enabling wider freedom on detecting various chemicals. The electron transfer process and mass transfer process have been studied quantitatively using the outer-sphere redox couple $\text{Ru}(\text{NH}_3)_6^{2+/3+}$, showing low iR drops and competitive ΔE_p under various $\text{Ru}(\text{NH}_3)_6^{2+/3+}$ concentrations. The capability of sensing various concentrations of dopamine (DA) has also been demonstrated using chronoamperometry. A linear response to various DA concentration of 0.5 μM to 100 μM was observed with a reasonably good sensitivity of 0.21 $\mu\text{A}/\text{cm}^2\cdot\mu\text{M}$.

Bio: Dr. Wen Li received the B.S. degree in material science and engineering from Tsinghua University, Beijing, and the M.S. and Ph.D. degrees both in electrical engineering from California Institute of Technology, Pasadena, in 2004 and 2008, respectively. She is currently an associate professor in the Department of Electrical and Computer Engineering at Michigan State University, East Lansing. Dr. Li is the recipient of the NSF CAREER Award (2011), the Best Application Paper Award at 3M-NANO (2011), and the Best Paper Award at International Neurotechnology Consortium (2013). She served as a member of the technical program committee or a session chair for a number of professional conferences, including IEEE EMBS Wearable Biomedical Sensors and Systems Technical Committee, IEEE MEMS, 3M-NANO, IEEE NANO, IEEE NEMS, IEEE BioCAS, and IEEE SENSORS. She is currently an expert reviewer for over 20 premiere journals and 10 refereed conferences in the fields of MEMS and microfluidics, biomedical engineering, neural engineering, and nanotechnology. She is a senior member of the IEEE, and a member of the American Chemical Society (ACS), the IEEE Engineering in Medicine and Biology Society (IEEE-BMES), the IEEE Eta Kappa Nu Honor Society (IEEE-HKN), and American Neurological Association (ANA).

▶ (3:30–4 p.m.) Professor Karolyn Hansen, CETRASE, University of Dayton (Invited)

Title: Nanostructured Surfaces for Biological Sensing Applications (Paper ID TFE17-35)

Abstract: Advances in the tools and technology for creating nanostructured surfaces present an opportunity for new and exciting advances in the field of biosensing. The application of nanostructure to biosensing devices has led to improvements in both sensitivity and selectivity in complex systems. This presentation will review recent advances and potential applications for integration of nanostructure into biosensing devices. Several forms of nanostructure will be discussed, such as nanorods, nanofibers, nanoparticles, and flexible graphene. In particular, we focus on the benefits of adding increased surface area for current sensor devices and the resultant device parameters. Our current research will be presented as a case study: the trials, tribulations, and successes in the integration of carbon nanorods and glancing angle deposited (GLAD) SiO_2 nanostructure with microcantilever sensors. A summary of current technology and a prospective look towards the future of nanostructure applications in biosensing devices will be presented.

Bio: Dr. Karolyn Hansen is an associate professor in the Department of Biology at the University of Dayton. She holds a joint appointment in the Department of Chemical Engineering's graduate bioengineering program. Dr. Hansen received her B.S. (biology) from The Pennsylvania State University, her M.S. (environmental toxicology) from Drexel University, and her Ph.D. in (marine science) from the University of Delaware. Her research interests are interdisciplinary in the areas of biomaterials and biosensors. Prior to joining the biology department, she worked as a senior research scientist in the materials division at the University of Dayton Research Institute, as a research scientist in the nanoscale science and devices group at Oak Ridge National Laboratory, as a senior research scientist in the surface chemistry branch at the U.S. Naval Research Laboratory, and as an assistant research scientist at the Chesapeake Biological Laboratory, University of Maryland. Dr. Hansen's current research focuses on the development of biosensors for aqueous and vapor phase detection of biomarker analytes, specifically the development of nanostructured sensors for biomarker detection over a wide dynamic range.

▶ (4–4:15 p.m.) (Contributed) Vishak Venkatraman, University of Cincinnati

Title: Thin Film Organic Light Emitting and Detecting Devices (Paper ID TFE17-14)

Abstract: The goal of this project is to create a point-of-care (POC) diagnostic device with several desirable characteristics, combining high sensitivity and semi-quantitative output in a cost effective and disposable package. Another important component of a POC system is power, and in this project, we are also exploring several options. The biosensor used in this project is lateral flow immunoassay (LFIA), which is a paper based device. LFIAs have several desirable characteristics such as capillary action and affinity to proteins that makes them ideal candidates for LOC applications. The POC described in this paper is a combination of LFIA and organic optoelectronics as the signal detection component. Organic light emitting diodes (OLEDs) and organic photodiodes (OPDs) have been found to be desirable candidates over their inorganic counterparts for POC applications. Organic devices provide the distinct advantages of being planar and large area in nature, which is suitable for the integration with LFIAs. Phosphorescence-based green OLEDs fabricated on plastic substrates were integrated as excitation light sources for fluorescent quantum dot (QD)-based LFIA devices. A 10x improvement in visual signal intensity was achieved compared to conventional LFIA, resulting in a 7x improvement in the limit-of-detection (LOD) of 3 nM concentration.

▶ (4:15–4:30 p.m.) (Contributed) Eric Frantz, University of Cincinnati

Title: Hybrid Manufacturing and Integration of Devices (Paper ID TFE17-17)

Abstract: LFA readers have been an existing technology for over a decade [1], and while the measurement techniques and accuracy used have evolved, the component packaging and fabrication methods have not. This has resulted in most modern LFA readers being rather large, rigid and having a plastic housing. Our work focuses on utilizing emerging hybrid manufacturing techniques and thin film batteries to improve on the design, portability, disposability and performance of traditional hand held LFA readers. In our work, hybrid manufacturing is used to replace traditional surface mounted device (SMD) components with solderless bare-die components. Switching to bare-die components allows for not only a smaller circuit footprint than SMD components but the height as well, creating a testing platform as thin as the LFA strip itself. Bare-die components also allow for the use of non-traditional flexible plastic PCBs, such as polyimide and PLA. Utilizing flexible circuitry, a circuit board was fabricated that can fold around an LFA strip. Sandwiching the LFA enables simple optical absorption measurements to be taken, as opposed to the traditional reflection based measurements, potentially increasing device sensitivity. Finally, thin film batteries are explored as a power supply due to their size and high operating voltage. Thin film batteries are lighter, thinner and more environmentally friendly than traditional batteries.

Reference:

- [1] Faulstich, K., Gruler, R., Eberhard, M., Lentzsch, D., and Haberstroh, K., "Handheld and portable reader devices for lateral flow immunoassays," [In lateral flow immunoassay], Humana Press, New York, 157-184 (2009).

NOTES:

Accepted Poster Papers

1. *Design and characterization of printed capacitors with high-k dielectrics used as thermometers*, Parthiban Rajan, Ohio University (Paper ID TFE17-6)
2. *High throughput experiments for selective chemical removal of metallic carbon nanotubes for thin film electronics*, Dr. Ahmad Islam, AFRL Materials and Manufacturing Directorate (Paper ID TFE17-8)
3. *Ultra-high contrast shutter with a tunable optical cavity*, Mohsen Jafari, University of Michigan. (Paper ID TFE17-9)
4. *Solid-state Li-ion battery, electrolyte/electrode interface engineering*, Ashish Gogia, University of Dayton (Paper ID TFE17-10)
5. *Thin-film Germanium for ultra-high energy density batteries*, Tongjie Liu, University of Dayton (Paper ID TFE17-11)
6. *Tunable color reflector with zero static power*, Mohsen Jafari, University of Michigan (Paper ID TFE17-16)
7. *Plasma assisted optimization of grain size and interface properties in thin film organic transistors*, Jason Wright, Ohio University (Paper ID TFE17-19)
8. *Thin-film lithium metal anode designs for lithium batteries*, Nicholas Vallo, University of Dayton (Paper ID TFE17-20)
9. *Defect inspection of optical thin-films using optical coherence tomography*, Dr. Mansik Jeon, Kyungpook National University, S. Korea (Paper ID TFE17-21)

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▶ (7–7:45 p.m.) PLENARY Dr. James Grote (AFRL Materials and Manufacturing Directorate)

Title: Biomaterials for Electronic and Photonic Applications (TFE17-39)

Abstract: Our work with biomaterials has evolved over the years to include not only deoxyribonucleic acid (DNA) and silk, but nucleobases as well. These are all abundant, inexpensive and non-fossil fuel-based green materials that will not deplete our natural resources or harm the environment. They have demonstrated the enhancement in the performance of electronic and photonic devices, such as light emitting diodes, thin film transistors, capacitors and electro-optic modulators. Preliminary in-house research in this biotechnology area started around 2000 with only a hand full of researchers, including members of our lab and members from Professor Naoya Ogata's lab at the Chitose Institute of Technology, Japan. It has grown into a large U.S., Asian and European consortium, producing hundreds of papers, two books and multiple patents. Included in this presentation will be the background of these biomaterials and applications, as well as our latest research using nucleobases. Nucleobases have similar electromagnetic and optical properties to those of DNA, but have much higher temperature stabilities, i.e., guanine has a temperature stability of 450°C. Using these nucleobase materials as passivation, buffer and charge blocking layers, we have achieved significant enhancements in device performance, yield and stability for graphene and two dimensional semiconductor-based transistors, polymer capacitors, phosphorescent organic light emitting diodes and non-linear optic polymer electro-optic modulators.

Bio: *Dr. James G. Grote is a principal electronics research engineer with the Air Force Research Laboratory, Materials and Manufacturing Directorate at Wright-Patterson Air Force Base, Ohio, where he conducts research in polymer and biopolymer based opto-electronics. He is also an adjunct professor at the University of Dayton, University of Cincinnati and Wright State University, teaching courses and directing research. Dr. Grote received his B.S. degree in electrical engineering from Ohio University and both his M.S. and Ph.D. degrees in electrical engineering from the University of Dayton, with partial study at the University of California, San Diego. He was a visiting scholar at the Institut d'Optique, Universite de Paris, Sud in the summer of 1995 and a visiting scholar at the University of Southern California, the University of California in Los Angeles and the University of Washington in 2001. He received Doctor Honoris Causa from the Politehnica University of Bucharest in 2010. Dr. Grote is an Air Force Research Laboratory fellow, a Fellow of the International Society for Optics and Photonics (SPIE), a fellow of the Optical Society of America (OSA), a fellow of the European Optical Society (EOS) and a senior member of the Institute of Electrical and Electronics Engineers (IEEE). In 2014, he was inducted into the Ohio University's Fritz. J. and Delores H. Russ, College of Engineering and Technology's Academy of Distinguished Graduates. He has co-authored over 220 journal and conference papers, plus two (2) books, seven (7) book chapters and six (6) patents, two (2) that are licensed with five (5) additional pending. His works have been cited more than 3755 times, and his current Hirsch index is 32. He has also served as editor for more than 25 conference proceedings and journal publications. Dr. Grote has presented over 120 papers and seminars, many of which have been keynote or invited. Dr. Grote has served as Chair for numerous international symposiums and conferences.*

NOTES:

Day 2 (Morning) — Tuesday, June 27, 2017

Time	Event	Location
8:45 a.m.–4 p.m.	Registration	Lobby

8:45–10:15 a.m.	Plenary Session	Marshall Room
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► **(8:45–9:30 a.m.)** Plenary IV Dr. Ben Leever, AFRL Materials and Manufacturing Directorate

Title: Flexible Hybrid Electronics: Enabling the Next Generation of Devices That Will Conform to the Shape of our Bodies and Vehicles (Paper ID TFE17-40)

Abstract: Flexible hybrid electronics (FHE) are based on the premise of combining flexible, unpackaged, or small silicon chips with traditional electronic manufacturing services processes, including printing on non-traditional substrates such as textiles and polymers. The combination of silicon electronics with innovative packaging schemes will deliver exciting new capabilities such as soft robotic prostheses, smart bandages that accelerate wound healing and inexpensive tags that can remotely monitor the shipment of pharmaceuticals or produce. Aerospace applications are expected to include array antennas integrated with air platform structures, wearable human performance monitors and structural health monitoring. This presentation will discuss the challenges and opportunities related to FHE, with a focus on NextFlex, the \$170M Manufacturing USA Institute created to establish a domestic manufacturing ecosystem in FHE. Roadmaps for both FHE technology and manufacturing processes will be discussed, and progress on NextFlex-funded projects will be shared.

Bio: Benjamin Leever is currently a senior materials engineer in the Air Force Research Laboratory (AFRL) Soft Matter Materials Branch. His primary roles are advanced development lead and government chief technology officer of NextFlex, a \$170M public-private partnership established to create a domestic manufacturing ecosystem in flexible hybrid electronics. In support of AFRL's investments in soft matter materials, Dr. Leever determines technical strategy, manages AFRL contracts, and establishes industrial, academic, and governmental collaborations. He also leads the directorate's Energy Integrated Product Team and represents the directorate on numerous domestic and international power and energy and additive manufacturing working groups. Prior to assuming his current duties, Dr. Leever led a research team focused on the development and modeling of multifunctional materials for structural power applications. Dr. Leever began his career at AFRL in the Manufacturing Technology Division, where he managed programs related to electro-optics systems. He earned a B.S. in chemical engineering from the University of Cincinnati and a Ph.D. in materials science & engineering from Northwestern University.

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Title: Integrated Magnetics and Multiferroics for Compact and Power Efficient Sensing, Power, RF, Microwave and mm-Wave Tunable Electronics (Paper ID TFE17-41)

Abstract: The coexistence of electric polarization and magnetization in multiferroic materials provides great opportunities for realizing magnetoelectric coupling, including electric field control of magnetism, or vice versa, through a strain mediated magnetoelectric coupling in layered magnetic/ferroelectric multiferroic heterostructures [1-8]. Strong magnetoelectric coupling has been the enabling factor for different multiferroic devices, which however has been elusive, particularly at RF/microwave frequencies. In this presentation, I will cover the most recent progress on new integrated multiferroic devices for sensing, memory, RF and microwave electronics. Specifically, we will introduce magnetoelectric multiferroic materials and their applications in different devices, including: (1) Ultra-sensitive magnetometers based on RF NEMS magnetoelectric sensors with picoTesla sensitivity for DC and AC magnetic fields, which are the best room temperature nano-scale magnetometers, (2) Novel ultra-compact multiferroic antennas with $\phi 200\mu\text{m} \times 1\mu\text{m}$ or $\lambda_0/600$ in size, -18dBi gain, ~0.2 percent bandwidth, self-biased operation and 1~2 percent voltage tunable operation frequency and (3) Novel GHz magnetic and multiferroic inductors with a wide operation frequency range of 0.3~3GHz, and a high quality factor of close to 20, and a voltage tunable inductance of 50 percent~150 percent. At the same time, I will also demonstrate other voltage tunable multiferroic devices, including tunable isolating bandpass filters, tunable bandstop filters, tunable phase shifters, magnetoelectric random access memory, etc. These novel integrated multiferroic devices show great promise for applications in compact, lightweight and power efficient sensing, power, RF, microwave and mm-wave integrated electronics.

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Bio: Nian Sun is professor at the Electrical and Computer Engineering Department, and director of the W.M. Keck Laboratory for Integrated Ferroics, Northeastern University. He received his Ph.D. degree from Stanford University. Prior to joining Northeastern University, he was a Scientist at IBM and Hitachi Global Storage Technologies. Dr. Sun was the recipient of the NSF CAREER Award, ONR Young Investigator Award, the Søren Buus Outstanding Research Award, etc. His research interests include novel magnetic, ferroelectric and multiferroic materials, devices and subsystems. He has over 200 publications and over 20 patents and patent applications. One of his papers was selected as the "ten most outstanding full papers in the past decade (2001~2010) in advanced functional materials." Dr. Sun has given over 100 plenary or invited presentations and seminars in national and international conferences and universities. He is an editor of *IEEE Transactions on Magnetics*, and of *Sensors*, and a fellow of the *Institute of Physics*, and of the *Institution of Engineering and Technology*.

10:15-10:30 a.m. COFFEE BREAK

NOTES:

Morning Sessions

Time	Session	Title	Location
10:30 a.m.–12 p.m.	Session 5A	Flexible and Printable Electronics	Marshall Room

Chairs: Dr. Carrie Bartsch and Dr. Emily Heckman, Air Force Research Laboratory, Sensors Directorate

► (10:30–11 a.m.) Professor Jay Guo (University of Michigan) (Invited)

Title: Thin Film Structures for Light Filtering and Energy Related Applications (Paper ID TFE17-23)

Abstract: In recent years, there has been increased interest to impart certain light responses to the surface of objects. For example, objects with certain artificial colors can be more appealing than others; thin film stacks or with patterned structures can provide versatile designs to achieve such properties, with thickness far thinner than the traditional colored pigment. Applying the design methodology to building integrated photovoltaics in the form of hybrid thin film structures allows harvesting of solar energy while producing colors compatible with the building appearance. Proper design of photonic structures can also modify the thermal emission properties of heated objects; e.g. more energy efficient incandescent lights can be envisioned. Ultra-thin and stable metal film can be exploited for transparent conductor applications, especially when coupled with anti-reflection dielectric coating, offering performance similar to that of commercial ITO while providing superb flexibility when coated on plastic substrate. Higher performance organic photovoltaics and OLED have been demonstrated. The guiding principles for achieving some of these optical properties, and scalable fabrication of such structures by roll to roll process will be discussed.

Bio: *L. Jay Guo started his academic career at the University of Michigan in 1999, and has been a professor of electrical engineering and computer science since 2011, with joint appointment in applied physics, mechanical engineering, macromolecular science and engineering. He has more than 200 refereed journal publications with over 22,000 citations and close to 20 U.S. patents. Many published works from his lab have been featured by numerous media. He is the recipient of the Research Excellence Award from the College of Engineering, and Outstanding Achievement Award in EECS at the University of Michigan. His group's research includes polymer-based photonic devices and sensor applications, hybrid photovoltaics, plasmonic nanophotonics, nanoimprint-based and roll to roll nanomanufacturing technologies.*

NOTES:

▶ (11–11:30 a.m.) Professor Alkim Akyurtlu, University of Massachusetts, Lowell (Invited).

Title: Additive Manufacturing for RF and Microwave Devices (Paper ID TFE17-5)

Abstract: There is growing need to adopt additive manufacturing for the production of RF/microwave electronics. This trend is motivated by the need for rapid prototyping and the production of RF systems that are flexible, lightweight, conformable and wearable. Printing RF electronics for DoD applications (e.g., radars, communication systems) is challenging since the requisite materials, components and systems demand higher performance than required for low frequency applications. This talk will describe research directed at developing RF subsystems based on additive technologies. Mainly, the development of a novel ferroelectric nano-ink for printing electrostatically-tunable dielectrics on flexible substrates using direct-ink writing methodologies such as inkjet printing, aerosol jet printing, and micro-pen dispensing techniques, will be described. This allows for realizing all-printed high-frequency voltage variable capacitors (varactors) on plastic films to be used in tunable RF and microwave applications.

Bio: *Alkim Akyurtlu received the B.S. degree in electrical engineering from the Virginia Tech, Blacksburg, in 1994, and the M.S. and Ph.D. degrees in electrical engineering from The Pennsylvania State University (Penn State), University Park, PA, in 1996 and 2001, respectively. In 2002, she joined the Department of Electrical and Computer Engineering at University of Massachusetts Lowell (UML), Lowell, MA, where she is a full professor, deputy director of Printed Electronics Research Collaborative (PERC) and co-director of the Center for Photonics, Electromagnetics and Nanoelectronics (CPEN). Her research interests are in design and application of metamaterials and additive manufacturing and printed electronics for RF and microwave applications. Her funding resources include the Air Force, NSF, DARPA, ONR and NASA.*

▶ (11:30–11:45 a.m.) Dr. Lee Harle, Michigan State University (Contributed)

Title: Recent 3D Printing Research Activities at Michigan State University (Paper ID TFE17-2)

Abstract: There has been a recent upsurge in research into three-dimensional printing (or additive manufacturing) in the microwave engineering community. A search on IEEE Xplore for “3D printed antenna” yields more than 100 papers for 2016 alone. These papers investigate 3D printing as options for fast prototyping and customizing of components for mobile communications, RFIDs, lenses, and flexible, wearable antennas, from mobile bands up to the THz regime, to cite just a few. Recent advances in 3D printing have enabled the research of complex components with microwave and millimeter wave-scaled dimensions, with fast turnaround and reduced cost compared to traditional cleanroom and PCB fabrication techniques. In this talk, I will give an overview of recent 3D printing activities at Michigan State University.

Bio: *Dr. Lee Harle has been a research assistant professor at Michigan State University since January 2013. Her research interests include microwave circuits, antennas and arrays, with a focus most recently on novel 3D printing techniques.*

NOTES:

Time	Session	Title	Location
10:30 a.m.–12 p.m.	Session 6A	Thin Films of Phase Change Materials and Sensors	Executive Dining Room

Chair: Professor Nelson Sepúlveda, Michigan State University, and Dr. Weisong Wang, CETRASE, University of Dayton

▶ (10:30–11 a.m.) Professor Punit Boolchand, University of Cincinnati (Invited)

Title: Amorphous Telluride Based Phase Change Materials and Network Rigidity (Paper ID TFE17-42)

Abstract: Reversible switching in Telluride glasses was discovered by S. R. Ovshinsky in the late 60s. Rigidity Theory was pioneered by J. C. Phillips in the late 70s, and it has evolved into a powerful tool to predict functionality of glassy or amorphous (a)-materials based on flexibility and rigidity of their networks. The glass forming tendency is optimized when networks are optimally constrained or isostatically-rigid, a condition that is met when $n_c = 3$. Here n_c denotes the number of mechanical constraints/atom due to bond-stretching and bond-bending forces, and 3, the degrees of freedom/atom in a 3D network. Stressed-rigid networks result when $n_c > 3$, while flexible ones form when $n_c < 3$, and both types of networks generally age. Isostatically-rigid networks are special- they are not only stress-free but show minimal aging. We will present new results on $a\text{-Ge}^x\text{Te}_{1-x}$ thin-films that reveal these 3 Topological phases with the composition x near 0.22 to be isostatically-rigid. The popular Phase Change Materials (PCM), such as $\text{Ge}_2\text{Sb}_2\text{Te}_5$, GeTe , Sb_2Te_3 , form stressed-rigid networks and thus age, leading resistivity of the a-phase to steadily increase with waiting time, which poses challenges to realize multi-level PCM and data storage over extended periods.

Bio: Punit Boolchand is a condensed matter scientist, a professor in the Department of Electrical Engineering and Computing Systems (EECS) in the College of Engineering and Applied Science (CEAS) at the University of Cincinnati (UC), where he is director of the Solid State Physics and Electronic Materials Laboratory. He is a University Distinguished Research Professor (STEMM). He discovered the Intermediate Phase: an elastically percolative network glass distinguished from traditional (clustered) liquid-gas spinodals by strong non-local long-range interactions. The IP characterizes space-filling, nearly stress-free and weakly-aging, critically self-organized non-equilibrium glassy networks (such as window glass, ineluctably complex high-temperature superconductors, microelectronic Si/SiO₂ high-k dielectric interfaces, and protein folding). His experimental data over a 25-year period (1982–2007) formed the basis for the theory of network glasses developed by James Charles Phillips and Michael Thorpe. The most remarkable physical properties of this new topological phase (IP) continue to attract special attention in applications of disordered materials including modified oxides and semiconducting glasses. The theory was adopted by Corning, Inc. and was a substantial factor contributing to the development of Gorilla glass by Corning scientists including John C. Mauro. These networks, although topologically disordered, exhibit many nearly ideal properties that have revolutionized glass science and technology, as part of HD TV and glass covers for devices such as cell phones. <http://www.ece.uc.edu/~pboolcha/>

NOTES:

▶ (11–11:30 a.m.) Professor Ron Coutu, Marquette University (Invited)

Title: Electronic Control of Germanium Telluride (GeTe) Phase Transition for Electronic Memory Applications (Paper ID TFE17-43)

Abstract: Germanium telluride (GeTe) is a phase change material (PCM) that undergoes an exponential decrease in resistance from room temperature to its transition temperature at approximately 200°C. Its resistivity decreases by as much as six orders of magnitude between amorphous and crystalline phases as it is heated. Chalcogenides such as GeTe have been utilized typically in nonvolatile optical memories such as CDs, DVDs, and Blu-ray discs, where the change in reflectivity between phases gives enough contrast for ON and OFF bits. Research over the past several years has begun to characterize the electronic control of PCM thin films for advanced electronic memory applications. By applying a voltage to control its resistance and crystallinity, GeTe has become a candidate for ultra-fast switching electronic memory, perhaps as an alternative to Flash memory. In this research, micro-scale PCM cells were fabricated using RF sputtering of a GeTe target and electron-beam evaporation on c-Si, SiO₂/Si, Si₃N₄/Si, and Al₂O₃. Characterizations of the crystallization process were completed with spectroscopic ellipsometry (SE), varied voltage, and varied temperature in order to draw a comparison of the switching mechanism between thermally and electronically induced transition. The results show an optical contrast of $\Delta n + i\Delta k = 0.858 + i1.056$. Heat conduction experiments prove a growth-dominated crystallization and fracturing of conductive crystallites when deposited on Al₂O₃. PCM cells exhibit memory-like I-V curves for smaller cell dimensions according to the trap-limited conduction model in chalcogenides. RF structures show the capability of being utilized as improved RF switches.

Bio: *Ronald A. Coutu, Jr. is a professor and the V. Clayton Lafferty Endowed Chair in electrical engineering at Marquette University, Milwaukee, WI. He received his B.S. in electrical engineering from the University of Massachusetts at Amherst in 1993, his M.S. in electrical engineering from the California Polytechnic State University (CalPoly) in San Luis Obispo in 1995, and his Ph.D. in electrical engineering from the Air Force Institute of Technology (AFIT) in 2004. In 2009, he retired from active duty Air Force after serving for 25 years. From 2008 to 2016, he was an AFIT assistant and associate professor and also the AFIT cleanroom director. He is a California registered professional engineer in electrical engineering and a senior member of the IEEE and SPIE. He is also a life member of the Tau Beta Pi and Eta Kappa Nu honor societies. His current research interests include microelectromechanical systems (MEMS), smart sensors, device fabrication, micro-electrical contacts and phase-change materials.*

▶ (11:30–12:00 p.m.) Professor Nelson Sepúlveda, Michigan State University (Invited)

Title: Wavelength-Selective Microactuators and Thin Flexible Microphone/Loudspeaker Devices. (Paper ID TFE17-44)

Abstract: Pushing existing technologies typically results in incremental improvements, which at some point saturate. At this point, the level of excitement and discovery begins to decrease and further advances require novel operation principles with new theoretical limits for performance. These further advances are typically found at the intersection of materials with supplementary advantages. In this talk, I will discuss the two most recent devices in my group that have benefited from this approach. The first one consists of the combination of single chirality carbon nano tube films with VO₂ thin films to produce wavelength-selective microactuators. The second device consists of exploiting the bi-directionality of ferroelectret nanogenerator (FENG) device to produce patches that can serve as microphones and loudspeakers.

Bio: *Nelson Sepúlveda is currently an associate professor in the Electrical and Computer Engineering Department with a courtesy appointment in the Mechanical Engineering Department at Michigan State University. He is a recipient of the NSF CAREER and the MSU Teacher-Scholar Award. He has participated in several summer faculty fellowship programs at the Air Force Research Labs and the Cornell Nanofabrication Facility. During the last year of his Ph.D. degree, he was Sandia National Laboratories, Microsystems and Engineering Sciences Applications (MESA) Fellow. Throughout his research career, he has been primarily focused on smart, multifunctional, phase-change materials. However, his recent demonstration of ferroelectret nanogenerators (FENG) has shaken the field and broadened the scope of wearable energy harvesters. His current research has been highlighted in several media reports.*

NOTES:

▶ (12:30-1:15 p.m.) Lunch Plenary Professor Akhlesh Lakhtakia

Title: Mimumes–Material Architecture Towards a Sustainable World (Paper ID TFE17-45)

Abstract: The methodologies of engineered biomimicry are inevitably pointing to the incorporation of multifunctionality in engineered materials when designing ever more complex systems. Optimal multifunctionality is also the defining characteristic of metamaterials. As fibrous materials are commonly manufactured from a variety of source materials, microfibrillar multifunctional metamaterials dubbed mimumes are industrially viable even today. The microfibrillar morphology of mimumes will enhance surface-dominated effects in comparison to those evinced by bulk materials. Poly(p-xylylene) polymers that are currently used in bulk non-fibrous forms for packaging and tribological applications in electronic and biomedical arenas are excellent initial candidates to fabricate mimumes. In microfibrillar forms, these polymers will display phononic, photonic, biomedical, and energy functionalities, thereby furthering the paradigm of design for system performance. Engineered multifunctionality will reduce resource depletion and energy consumption, making it an important route towards sustainability. However, it could also enhance disposal costs, making the lifecycle audit an even more important part of engineering practice.

Bio: Akhlesh Lakhtakia received his B.Tech. (1976) and D.Sc. (2006) degrees from Banaras Hindu University, and MS (1981) and Ph.D. (1983) degrees from the University of Utah. In 1983, he joined the Department of Engineering Science and Mechanics at Penn State as a post-doctoral research scholar, where he became a distinguished professor in 2003 and the Charles Godfrey Binder Professor in 2006. His current research interests include electromagnetic scattering, surface multiplasmonics, bioreplication, forensic science, solar energy, sculptured thin films, and mimumes. He has been elected a fellow of Optical Society of America (1992), SPIE (1996), Institute of Physics (UK) (1996), American Association for the Advancement of Science (2010), American Physical Society (2012), Institute of Electrical and Electronics Engineers (2016), Royal Society of Chemistry (2016), and Royal Society of Arts (2017). He has been designated a distinguished alumnus of both of his almae matres at the highest level. Awards at Penn State include: Outstanding Research Award (1996), Outstanding Advising Award (2005), Premier Research Award (2008), and Outstanding Teaching Award (2016), and the Faculty Scholar Medal (2005). He received the 2010 Technical Achievement Award from SPIE and the 2016 Walston Chubb Award for Innovation from Sigma Xi.

NOTES:

Afternoon Sessions

Time	Session	Title	Location
1:45–3:15 p.m.	Session 5B	Flexible and Printable Electronics	Marshall Room

Chairs: Dr. Carrie Bartsch and Dr. Emily Heckman, Air Force Research Laboratory, Sensors Directorate

► (1:45–2:15 p.m.) Professor David Estrada, Boise State University (Invited)

Title: Emerging Materials for Aerosol Jet Printing (Paper ID TFE17-3)

Abstract: The market for flexible and printed electronics is growing rapidly and is currently estimated to be a multi-billion-dollar industry. [1] Recent advances in the synthesis of 2D materials-based inks has increased the design space for inkjet printed flexible and printed optoelectronic devices. [2-4] However, much work remains to be done to extend 2D material inks to aerosol jet printing (AJP), and fully understand the fundamental limits of energy dissipation in optoelectronic devices manufactured via AJP. In this study, we investigate the performance of graphene and MoS₂-based devices deposited via AJP. We use chemical exfoliation to obtain graphene [5] and MoS₂ flakes [6], and characterize them by various microscopy methods. The graphene flakes range in thickness (tg) from monolayers to thicker graphite flakes (tg=16 ± 15 nm) with lateral dimensions from 50 - 200 nm. To synthesize the inks, we disperse the flakes in 92 percent cyclohexanone and 8 percent terpineol. [7] The concentration of graphene and MoS₂ is confirmed by UV-Vis measurements as 3.5 mg/ml and 1.3 mg/ml, respectively. To probe the electrical performance of the graphene ink, we print transmission line method (TLM) test structures with silver contacts using an Optomec AJ-300 printer equipped with a UA-Max ultrasonic atomizer. A recirculating bath temperature of 15°C is used to stabilize the ink temperature and prevent the output from being solvent rich. The platen temperature, nozzle diameter, and gas flow are also optimized to ensure print quality. For the printed graphene interconnects, we find the electrical resistance scales with increasing pass number (n). The lowest sheet resistance obtained is ~1.5 kΩ/□ for n=50. To understand the role of thermal resistance (RTH) in energy dissipation we employ a combination of electrical breakdown thermometry and IR microscopy on various substrates which span thermal conductivities of 0.1 Wm⁻¹K⁻¹ to 100 Wm⁻¹K⁻¹. Our results provide new insight into structure-property-processing correlations in printed 2D material devices, with broader implications for the reliability of printed and flexible electronics.

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Bio: David Estrada is an assistant professor in the Micron School of Materials Science and Engineering at Boise State University. He earned his Ph.D. and M.S. from the University of Illinois at Urbana-Champaign in electrical engineering, where he was a NSF and a NDSEG fellow. His undergraduate degree was also in electrical engineering from Boise State University. He is a veteran of the United States Navy, having served aboard the guided missile destroyer, U.S.S. Curtis Wilbur, during Operation Enduring Freedom.

NOTES:

▶ (2:15–2:45 p.m.) Dr. Carrie Bartsch, AFRL Sensors Directorate (Invited)

Title: Overview of Research on Printable Electronics at AFRL Sensors Directorate (Paper ID TFE17-47)

Abstract: The Sensors Directorate of the Air Force Research Laboratory (AFRL) began studying non-traditional fabrication techniques for electronic devices in 2011 with the purchase of a nano-imprint lithography system. Since then, we have grown our capabilities to include four printers, and some pre- and post-processing systems. We have studied a variety of different devices, and we have gained a repertoire of material testing techniques ranging from measuring film thickness, surface roughness, and line widths, to studying adhesion, to determining resistance and RF parameters of the printed films. This paper brings together these techniques and results to show the future potential for non-traditional fabrication.

Bio: *Carrie M. Bartsch is an electronics research engineer with the Devices for Sensing branch in the Sensors Directorate of the Air Force Research Laboratory. She is technical co-lead for the Printronics Research Group, where our research is focused on the use of non-traditional fabrication techniques for electronic and photonic devices. Prior to working for the U.S. Air Force, Dr. Bartsch worked as a government contractor where she investigated the enhancement of silicon photonics by electro-optic polymers; characterized the electrical properties of biopolymers, including DNA-CTMA and BSA-PVA, from DC to microwave frequencies; and demonstrated the first use of DNA-biopolymers as a semiconducting layer in field effect transistors. Dr. Bartsch is an IEEE senior member. She earned her Ph.D. in electrical engineering from the University of Dayton in 2007, her M.S.E. in electrical engineering from the University of Michigan in 2002, and her B.S. in electrical engineering from the University at Buffalo in 2000.*

▶ (2:45–3:05 p.m.) Dr. Sheng Xu, University of California San Diego (Contributed)

Title: A Hybridized Approach to Soft Electronics (Paper ID TFE17-4)

Abstract: Wearable devices that are capable of acquiring multichannel physiological signals from the human body represent an important trend for healthcare monitoring, consumer electronics, and human-machine interface. The resulting search for pliable building blocks calls for approaches to bridge the gap between conventional high performance hard materials and soft biology. Combined strategies of materials design and advanced microfabrication on the system level present unique opportunities. In this presentation, I will discuss a rationally designed “island-bridge” matrix that allows hybridizing hard materials with soft substrates. Specifically, the hard components are integrated on the predefined distributed islands, and the wavy bridges will buckle out of the plane to absorb the externally applied stress. The result is a fully functional system that is rigid locally in the islands, but soft globally that enables conformal integration with the curvilinear human body. Demonstrated prototypes include a multichannel health monitor that can sense local field potentials, temperature, and acceleration, and wirelessly transmit the acquired data to the backend receiver. This is a platform technology, which holds profound implications for integrating a broad range of sensors, actuators, and circuit components, for diagnosing and treating a broad range of health conditions.

Bio: *Professor Sheng Xu was appointed in July 2015 as a member of the faculty in the Department of NanoEngineering at UC San Diego. Xu was a postdoctoral research associate in Frederick Seitz Materials Research Laboratory from 2011 to 2015 at University of Illinois at Urbana-Champaign, where he developed advanced wearable electronic systems for healthcare and energy applications. He received his Ph.D. in materials science and engineering in 2010 at Georgia Institute of Technology, focusing on oxide nanowire arrays for energy sciences. He obtained his B.S. in chemistry and molecular engineering from Peking University in Beijing, China in 2006. His research has been recognized by several awards, including the most recent 3M Non-Tenured Faculty Award and Samsung Global Research Outreach Award.*

NOTES:

Time	Session	Title	Location
1:15–1:45 p.m.	Session 6B	Thin Films of Phase Change Materials and Sensors	Marshall Room

Chair: Professor Punit Boolchand and Dr. Weisong Wang, CETRASE, University of Dayton

▶ (1:15–1:45 p.m.) Professor Kaushik Dayal, Carnegie Mellon University (Invited)

Title: Multiscale Modeling and Computation for Functional Thin Films (Paper ID TFE17-46)

Abstract: Defects play a central role in enabling the key properties of many important functional and electronic materials that are relevant to electronic and energy storage/conversion/sensing devices. For example, the electromechanics of ferroelectrics is achieved through the nucleation and growth of domain wall defects; solid oxide ionic conduction is achieved through the motion of point defects; and geometric features — e.g. free surfaces and patterned electrodes in thin-film geometries — that act as defects in that they destroy periodicity. These problems are generically multiscale in nature; it is important to resolve both the electron / atom scale at the defect, as well as the specimen scale to account for realistic boundary conditions. They are also generically multiphysics, and couple deformation, electric field, and atomic interactions. I will discuss our research efforts that develop computational and mathematical multiscale methods for a range of length scales and physical models, including mesoscale real-space phase-field, multiscale atomistics based on the quasi-continuum method, and tight-binding and density functional theory for the electronic structure of defects and electron scattering at defects.

Bio: *Kaushik Dayal is a professor of engineering at Carnegie Mellon University. He received his B.Tech. at the Indian Institute of Technology Madras and his M.S. and Ph.D. in mechanical engineering at Caltech. His research interests are in the area of theoretical and computational multiscale methods applied to functional materials and electromagnetic effects. His research has been recognized by young investigator awards from ARO, AFOSR and NSF, and the Eshelby and Leonardo da Vinci medals, and he has held visiting appointments at the University of Bath, University of Bonn and Air Force Research Lab.*

NOTES:

Time	Session	Title	Location
1:15–2:45 p.m.	Session 7	Meta-Materials and Optical Thin films	Executive Dining Room

Chairs: Professor Partha Banerjee and Professor Joseph Haus, CETRASE, University of Dayton, USA

► (1:15–1:45 p.m.) Dr. Carl Liebig, AFRL Materials and Manufacturing Directorate (Invited)

Title: Ultrafast Laser Precipitation of Electro-Optic Materials and Structures in Glass (Paper ID TFE17-48)

Abstract: Nonlinear optical (NLO) crystals are the fundamental building blocks for electro-optic applications. For example, the conversion of laser wavelengths through parametric processes require large and aligned, single crystals that are essential in creating tunable laser sources for generating coherent light from the ultraviolet to the infrared. The development of novel NLO crystals is difficult as it requires bulk techniques with long growth times, expensive equipment, and often results in low quality crystals. Over the last decade, femtosecond modification of transparent materials has moved beyond simply changing the refractive index to create optical structures, to growing NLO crystals in custom supersaturated glasses. This novel growth technique is capable of fabricating single NLO crystalline structures with a well aligned the polar axis. It has been shown that precipitation of NLO crystals in glass has the potential to be a low-cost method of creating functional electro-optical elements. In this presentation, I will discuss recent work at AFRL where a widely used electro-optical crystal, Lithium Niobate (LiNbO_3), was precipitated in $33\text{LiO}_2\text{-}33\text{Nb}_2\text{O}_5\text{-}34\text{SiO}_2$ (mol%) (LNS) glass, forming NLO structures in an amorphous matrix. Several aspects of this project will be explored in detail: the fabrication techniques for making high quality supersaturated glass solutions, the crystallization parameters for continuous femtosecond laser induced crystal growth, and the measurement of the orientation of the precipitated lithium niobate for a variety of writing conditions.

Bio: *Carl M. Liebig is a research physicist with the Materials and Manufacturing Directorate of the Air Force Research Laboratory. He received his Ph.D. in physics from The University of Georgia in 2006, with emphases in experimental and computational nonlinear optics. He was a postdoctoral research fellow at Laboratoire Hubert Curien in Saint Étienne, France, and a postdoctoral researcher at Purdue University's Birck Nanotechnology Center. Since arriving at AFRL in 2010, his research interests have included ultrafast laser interactions with matter, laser source materials and applications of nonlinear optical materials.*

NOTES:

► (1:45–2:15 p.m.) Professor Sergei Lyuksyutov, University of Akron (Invited)

Title: Modifications of Si (100) Using Atomic Force Microscopy in the Presence of Propan-2-ol, Butan-2-ol or Toluene (Paper ID TFE17-49)

Abstract: Under ambient humidity conditions, ultra-sharp n-doped silicon tips (spike radius ~ 1 nm) oscillating at 160-250 kHz generate raised nanostructures ~50-200 nm wide and ~ 2 nm high on un-doped or p-doped Si (100) surfaces pretreated with propan-2-ol, butan-2-ol, or toluene of varying degrees of polarity. It is suggested that mechanical stress associated with the oscillatory Hookean energy (~ 5-15 eV) of the tip promotes cleavage of residual solvent bonds. We have proposed that the materials needed to create the observed nanostructures are by-products of cleaved solvent molecules, which then form chemical bridges with the surface. This may lay the foundations for applications in energy conversion, data storage and photonics including metamaterials.

Bio: *Sergei Lyuksyutov has earned his degrees from Moscow Institute of Physics and Technology: M.S. in physics and engineering (Advisor: Professor N.G. Basov) in 1984, and Ph.D. in physics in 1991. His dissertation title was "Hybrid lasers based on photorefractive materials." He was awarded George Soros Fellowship (Advisor: Professor L. Solymar) at Oxford University, Hertford College, UK (1989-1990). He was a postdoctoral (1994-1997) at the Technical University of Denmark (Advisor: Professor P. Buchhave), and also served as a visiting professor at the Technical University of Denmark (2001), National Research Council summer faculty fellow at U.S. Air Force Laboratory at Wright-Patterson AFB (2002-2004), Japan Society Promotion for science fellow at Institute of Technology in Tokyo, Japan (2004-2005), Fulbright Senior Specialist at the Institute of Physics, Kiev, Ukraine (2008), NASA summer faculty fellow at Glenn Research Center (2010-2011, 2014, 2016), and senior fellow at Naval Research Laboratory, Washington D.C. (2012-2013). He has published 50 papers (peer-reviewed journals only), and delivered 150+ contributed and invited talks at international (Japan, France, UK, Germany, Denmark, Poland, Check Republic, Ukraine, and Russia) and national APS, ACS, OSA, SPIE meetings. Sergei is a member of American Physical, Chemical societies, and also SPIE. His current research interests are in the areas of physics of materials with emphasis on atomic force microscopy, mathematical modeling using MATLAB and COMSOL, and also in experimental nonlinear optics.*

► (2:15–2:45 p.m.) Dr. Chenlong Zhao, CETRASE, University of Dayton (Invited)

Title: Manipulate Light and Particles on a Surface Based on Optothermally Generated Surface Bubbles (Paper ID TFE17-7)

Abstract: An optothermally generated surface bubble (OGSB) refers to a micro/nano sized bubble that is formed on a liquid-solid surface. The OGSB is generated on the surface by heating the surface with a continuous-wave laser. Under laser illumination, the liquid-solid surface can be heated up to a temperature that is much higher than the boiling point of the liquid. Above a certain threshold of the laser power, a micro or nano-sized bubble can be generated on the laser-illuminating area on the surface. The bubble keeps in contact with the surface and allows for non-invasive control of both light and heat at the micro/nanoscales on the surface. The position, size, and shape of the OGSB can be precisely and dynamically changed by modulating the laser beam. Therefore, the OGSB enables many intriguing applications ranging from the micro/nano-manipulation of fluids, particles, cells, and light to the synthesis of micro/nano-structures under ambient conditions. In this work, we will demonstrate how an OGSB can be used to dynamically control a two-dimensional light, known as surface plasmon polaritons (SPPs), on a gold thin-film. We will also demonstrate the manipulation of both micro and nano-sized particles with the OGSB.

Bio: *Dr. Chenglong Zhao is an assistant professor at University of Dayton with a joint appointment at the Department of Electro-Optics & Photonics and Department of Physics. He received his Ph.D. from Peking University (Beijing, China) in 2011. Then, he carried out postdoctoral research at the Pennsylvania State University and National Institute of Standards and Technology (NIST). Dr. Zhao's research interests include nanomanufacturing, nanophotonics, nanomanipulation, plasmonics, and bio-sensing. He has authored and co-authored over 20 journal papers including Nature Communications, Nano Letters, ACS Nano, Nanoscale, and Lab Chip. His research findings have been widely reported by Science Daily, Physics News, National Science Foundation, Science Codex, Science News, Nano Werk, et al.*

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▶ (2:45–3:15 p.m.) Professor Jay Mathews, University of Dayton

Title: Germanium-Tin Thin Film Alloy Materials for Silicon Photonic Devices (Paper ID TEF17-50)

Abstract: Silicon is the basis for a multi-billion dollar industry, but its optical properties have limited its use in optoelectronics for infrared (IR) applications. Many IR devices are currently made using III-V or II-VI materials, which has served to fill the gap. However, these materials tend to be expensive, and integrating the materials and devices into Si fabrication can be difficult. There are a number of applications that could benefit from Si integrated photonics including photovoltaics, infrared detection and imaging, optical interconnects (OICs), and photonic integrated circuits (PICs). In particular, OICs and PICs require efficient laser sources, modulators, low loss waveguides, optical switches, and photodetectors, all of which must be integrated into a single Si chip using complementary metal-oxide-semiconductor (CMOS) processing.

One possible solution to realizing some of these devices is to use GeSn alloys as the active material. These thin films are grown on Si substrates and compatible with standard Si processing techniques, they have band gaps in the infrared, and the band structure of GeSn yields more efficient optical absorption and emission than that in Si. These unique properties have prompted a recent effort to develop optoelectronics from GeSn films, and this research has resulted in a number of prototype photonic devices such as photodetectors that cover all telecommunications wavelengths, infrared light-emitting diodes, and optically-pumped waveguide lasers. I will review some of this recent work and discuss the future impact of this exciting material for silicon photonics.

Bio: *Dr. Jay Mathews is currently an assistant professor in the Department of Physics and affiliated faculty in the Department of Electro-Optics and Photonics at the University of Dayton. He obtained his B.S. with double major in physics and mathematics from Colorado State University in 2007, and he received his Ph.D. in physics from Arizona State University in 2011. Following graduation, Dr. Mathews was awarded a fellowship in the National Academy of Sciences Research Associateship Program, where he performed research at U.S. Army ARDEC–Benet Laboratories at Watervliet Arsenal in NY until July 2013. He started at University of Dayton in August 2013. He is currently funded by U.S. Army ARDEC, Office of Naval Research and the Air Force Office of Scientific Research. He received an AFOSR Young Investigator Award in 2016.*

3:15–4 p.m. COFFEE & REFRESHMENTS (Marshall Room)

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THANK YOU FOR YOUR PARTICIPATION IN THE SECOND WORKSHOP ON THIN FILMS FOR ELECTRONICS, ELECTRO-OPTICS, ENERGY AND SENSORS (TFE3S)!