PURDUE UNIVERSITY | Birck Nanotechnology Center
DISCOVERY PARK

Birck Research Staff Symposium

September 19, 2018 Wednesday
8am-1:40pm @ BRK 1001

- *One-stop resource to learn major BRK technical capabilities/services and related research from staff scientists/engineers!*
- *Each staff talk is 30 min (24-min presentation + 6 min Q&A)*
- *Lunch provided, with a 30-min panel discussion with all staff speakers*

Time	Presentation/Agenda
8:00-8:10am	Opening Remarks
8:10-8:40	Yi Xuan: "**Electron-Beam Lithography at Birck Nanotechnology Center**"
8:40-9:10	Nicholas Glassmaker: "**Roll-to-Roll Processing at Birck Nanotechnology Center**"
9:10-9:40	Tim Kwok: "**3D Cell Culture Core (3D3C) Facility: A Breadth of Services in Biological and Engineering Research**"
9:40-10:10	Nithin Raghunathan: "**Microfabrication, Characterization and Sensor development in the Industrial Space**"
10:10-10:30	Coffee Break
10:30-11:00	Rosa Diaz: "**Upcoming Electron Microscopy Capabilities at Purdue University: Structural, chemical and electronic characterization at the atomic level of complex nano-materials**"
11:00-11:30	Dmitry Zemlyanov: "**Chemical and Electronic Properties of Solid Surfaces**"
11:30-12:00	Neil Dilley: "**Materials Characterization at high magnetic fields and extreme temperatures, with a focus on magnetism**"
12-12:30pm	Alexei Lagoutchev: "**Birck Optics and Spectroscopy Lab / Optics recharge Center, recent updates**"
12:30-1:00	Lunch Break
1:00-1:30	Panel Discussion (& continued lunch)
1:30-1:40	Conclusion

Questions/Contact: Yong P. Chen (yongchen@purdue.edu)

PURDUE UNIVERSITY Discovery Park

Yi Xuan

Yi Xuan received his B.S. degree in Applied Chemistry from East China University of Science and Technology, and Ph.D. degree in Inorganic Materials from Tokyo Institute of Technology. He joined Purdue University in 2005 as a post-doctoral researcher and has been working on various projects in the field of nanofabrication, nano-CMOS and nano-photonics etc. He has authored and co-authored more than 100 publications with 5000+ citations. He is currently a Research Assistant Professor at Birck Nanotechnology Center and a member of IEEE and OSA.

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Electron-Beam Lithography at Birck Nanotechnology Center

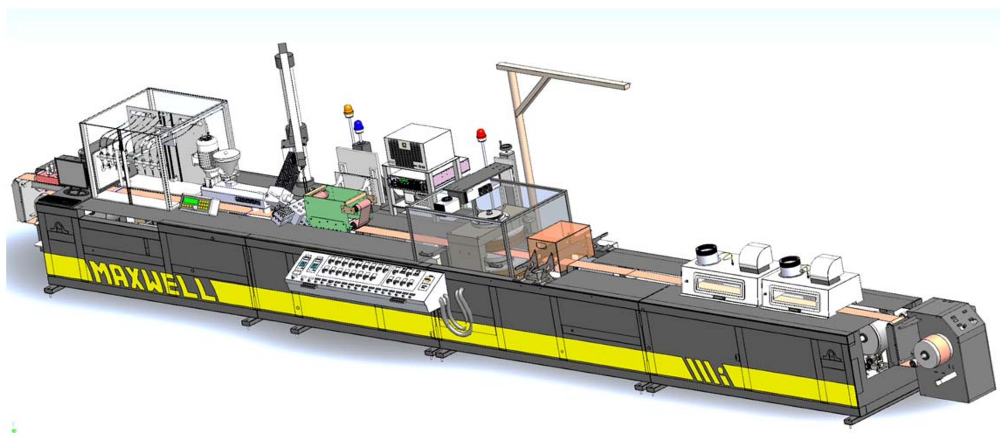
With the development of advanced processing technology, electron-beam lithography (EBL) is a key enabling tool for nanoscience and nanofabrication. At Birck Nanotechnology Center (BNC), a lot of research, such as MOSFET, metamaterials, photonics, and NEMS, rely heavily on EBL to prove research concepts and carry out fundamental science. Recently, BNC installed the JEOL-8100 EBL system in its cleanroom. It has a minimum beam diameter of 5.4 nm at 1,000 um x 1,000 um field size with maximum scan speed of 125MHz. In this talk, I will focus on doses for different EBL resists, stitching errors and alignment considerations. I will also highlight some common user mistakes and what can be done to prevent them.

Nicholas Glassmaker

Nicholas Glassmaker joined Birck Nanotechnology Center in Fall 2017 and has an educational background in mechanical engineering and applied mechanics, receiving the Ph.D. degree from Cornell University in 2004. He completed post-doctoral assignments at Lehigh University and the Ecole Superieure de Physique and Chimie Industrielles in France. He also has 10 years' experience working in the Central R&D and Electronic Materials departments at DuPont Co. in Wilmington, DE. During these various assignments, he has become skilled at microfabrication techniques, polymer processing and surface modification, testing mechanical properties of materials, and materials development for screen printing inks.

Roll-to-Roll Processing at Birck Nanotechnology Center

Flexible substrates present the ability to process materials in a roll-to-roll manner for high throughput, low cost, and excellent uniformity. Examples of areas where such processes are utilized include polymer coatings and films, printing, and the rapidly growing field of flexible electronics. Birck Nanotechnology Center has a range of tools for carrying out both printing and coating operations, which will be described in this talk, such as the PPSI roll-to-roll ink jet printer, Mirwec coating system, and the newly installed Maxwell roll-to-roll system. The Maxwell system is a state of the art, custom piece of equipment designed by Prof. Mukerrem Cakmak, which offers a broad range of polymer processing operations, including a unique particle alignment capability via applied electric and magnetic fields.



Relevant examples of research enabled by these tools will be presented, which include: printed conductive electrodes for flexible electronics, ion selective membrane depositions for sensor applications, and cast polymer films with aligned piezoelectric particles for sensitive pressure sensing. Additionally, supporting tools and instruments useful for rapid process development will be described.

Tim Kwok

Tim Kwok, Ph.D. , Cancer Biology and Radiation Biology,Facility Manager, 3D Cell Culture Core Facility, Birck Nanotechnology Center

In addition to research projects, 3D3C is also involved in education and training in cell culture.

Four in-house workshops have been developed covering basic cell culture techniques, basic 3D cell culture techniques, microscopic visualization of 3D cell cultures and an upcoming organ-on-a-chip topic. The 2-day workshops typically include a lecture, discussion sessions, demonstrations and two half-days for hands-on practice. Over the past two-and-a-half years, more than 100 Purdue members have been trained through our workshops. Training documents and short demonstration videos created for some of the workshops are posted on NanoHub; basic cell culture techniques (https://nanohub.org/resources/22645), basic 3D cell culture techniques (https://nanohub.org/resources/25058), Moreover, 16 newsletters have been disseminated so far

that present relevant research done at Purdue and discuss hot topics related to 3D cell culture (https://nanohub.org/groups/3d3cfacility/news);

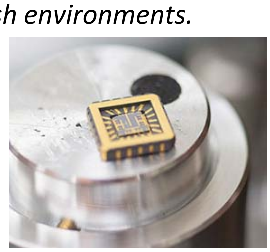
3D Cell Culture Core (3D3C) Facility: A Breadth of Services in Biological and Engineering Research

The mission of the 3D Cell Culture Core (3D3C) facility is to provide access and expertise in the art of 3D cell culture for basic and translational research projects. By fostering interaction between engineers and biologists our aim is to facilitate the development and implementation of optimal cell culture models. To achieve this aim, our activities are geared toward education and training, project development, and being a home for specific research endeavors. Our interactions with faculty and trainees span various departments from Engineering, Physics to Biological Sciences, Biochemistry, Chemistry, Industrial and Physical Pharmacy, Health and Kinesiology, Comparative Pathobiology and currently deal with projects related to cancer (breast, bladder, glioblastoma, head & neck), aging, liver metabolism, biomaterial development and applications for neuroscience. The 3D3C is leading new directions for research with organs-on-a-chip (or tissue-chips) via collaborations, staff-for-hire services and its own projects that bring new models needed for research programs of the Purdue community. Here we present the 'big tumor' project led by 3D3C and done in collaboration with engineers and pathologists. Producing tumors with minimum sizes detected *in vivo* (at least 0.5 cm in diameter) will allow researchers to better understand tumor biology and improve drug delivery and the testing of engineered devices to fight cancer. However, one of the challenges to overcome is the production of tumors in which cells do not heavily die by necrosis due to the lack of oxygen and nutrients. Rare published reports show big tumors formed by cell aggregation over a 24-hour period, with extended necrosis in their center. Yet, these conditions do not allow *in vivo*-like tumor organization, and only a small subset of tumor types is indeed characterized by extended necrosis. With our method we can produce, within a few days, tumors up to 1.5 cm in diameter in which cells reproduce the pathological traits of the cancer type represented by these cells, as measured by cellularity, morphology, budding and nuclear pleomorphism. Tumors are viable for several days, show delivery of anticancer drugs throughout and can be made heterogeneous for cell phenotypes as *in vivo*. The 'big tumor' method will now be applied for projects supported by a Showalter award focused on the impact of heterogeneous concentrations of immune cells on cancer phenotype as a collaboration with Dr. Matosevic.

Reference: Lelièvre SA, Kwok T, Chittiboyina S. Architecture in 3D cell culture: An essential feature for *in vitro* toxicology. *Toxicol In Vitro.* 2017 Dec;45(Pt 3):287-295

Nithin Raghunathan

Nithin Raghunathan received his Ph.D in electrical engineering from Purdue University, West Lafayette, IN, USA, in 2014. His dissertation focused on the development on micro-machined g-switches for impact applications typically in the ranges of 100 – 60,000 g's. He worked as Post-Doctoral Research associate from 2014 to 2015 and was involved in the development of wireless radiation sensors for dosimetry applications. He is currently a Staff Scientist at the Birck Nanotechnology Center at Purdue University. His current research focus is in the development of sensors for pharmaceutical lyophilisation and aseptic processing. His other interests include novel MEMS inertial devices, development of new microfabrication techniques, wireless and flexible sensors and Internet of things (IoT) and also sensors for industrial and harsh environments.



High-G sensor

Microfabrication, Characterization and Sensor development in the Industrial Space

The Birck Nanotechnology center offers a variety of capabilities especially in general microfabrication, electrical and physical characterization. With regards to microfabrication, the center features a variety of toolsets to enable fabrication of most devices from scratch to finish. These include lithography tools, such as aligners, metallization tools, such as evaporators and sputters, processing tools, such as etchers, and finally packaging tools, such as wire bonders, dicing saws, and pick-and-place systems. In addition to the fabrication capabilities, the center has a large selection of electrical and surface characterization systems, such as different types of probe stations and confocal microscopes to name a few. In each of these categories, the center features some unique tools such as maskless aligners, etc that could be of great benefit to the user.

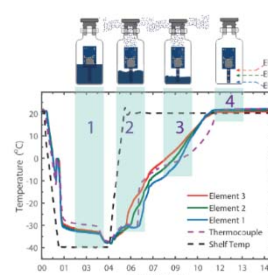
An example of the application of these tools would be the development of sensors particularly for industrial applications. This includes the development of MEMS devices for detecting impact forces in 100-60,000 g regimes using silicon cantilevers as the detection mechanism. Another example is a real-time MOS-based wireless electronic radiation dosimetry utilizing Bluetooth technology for occupational environments. These sensors are capable of detecting 100 mrem radiation doses in real-time and transmitting the data wirelessly to a nearby base stations. Another developed sensor is a wirelessly powered multi-point temperature sensor for lyophilisation to monitor pharmaceutical drug productions. These sensors feature wirelessly powering, small form-factor and mesh network technologies allowing operation of >100 sensors in a single environment. Other developing research efforts at Birck include the IoT network deployment of in situ fabricated sensors for Agriculture and Manufacturing.

PMC 200 Probe station

XEF2 Dicing Saw

DiscoDAD 641 Dicing Saw

Electronic Dosimetry



Multi-point Sensor

References

S. Scott et al., "MOS-capacitor-based ionizing radiation sensors for occupational dosimetry applications," 2015 IEEE SENSORS, Busan, 2015, pp. 1-4.

N. Raghunathan, X. Jiang, A. Ganguly and D. Peroulis, "An ANT-based low-power battery-free wireless cryogenic temperature probes for industrial process monitoring," *2016 IEEE SENSORS*, Orlando, FL, 2016, pp. 1-3.

***Rosa E. Diaz**, Birck EM Core staff scientist.*

Rosa has over 8 years of experience on aberration corrected transmission electron microscopes (TEM) and environmental TEM (E-TEM). She graduated from Arizona State University in 2010 with a PhD in Materials Science and Engineer. She later went to work as a postdoc at Brookhaven National Laboratory under the supervision of former Purdue alumni Eric Stach. Her work involved the design and implementation of in-situ experiments to study catalytic systems as well as growth of 1D nanostructures using an image-corrected E-TEM and a probe-corrected STEM. Subsequently, she moved to Okinawa Institute Science and Technology as a staff scientist to work with their aberration corrected and monochromated E-STEM. Her work focused mainly on using advanced analytical techniques to study modifications of nanoparticle systems with applications in biomedicine. Rosa has been at Birck for 3 years assisting Birck users with understanding the structural and chemical characteristics of their nanomaterials ranging from optoelectronics, catalysis, and metallic alloys to biomaterials. She is also the microscopist for the Microsoft Station Q Purdue Project under the direction of Prof. Michael Manfra. Rosa's main research interest focuses on understanding superconducting-semiconductor interface with high resolution TEM and STEM, understanding plasmonic and biomaterials with high resolution EELS, and studying the modification of materials in-situ under changing temperature and gas conditions.

Upcoming Electron Microscopy Capabilities at Purdue University: Structural, chemical and electronic characterization at the atomic level of complex nano-materials

The acquisition of new state of the art TEM – Themis Z – at Birck Nanotechnology Center will enable users across a wide range of research areas to acquire a higher understanding of nano- materials at the atomic level. Researchers at Birck will be able to gain fundamental understanding of the materials' physical and chemical properties and a proper correlation between these properties and morphology at the nanoscale. The Thermo Fisher Themis Z TEM is equipped with a probe and image aberration correctors to assure sub-angstrom resolution in STEM and TEM across the entire acceleration voltage range of 60 to 300 kV, the microscope delivers a STEM and TEM resolution down to 60 pm at 300kV and 140 pm and 180 pm at 60kV (Figure 1). The Themis Z TEM is also is equipped with a monochromator and Electron Energy Loss Spectrometer (EELS) to EELS spectrometer that assures an energy resolution of 80meV at 60kV to suit all EELS applications. This kind of energy resolution will enable researchers at Birck to study plasmonic structures or any other material with emissions in the visible range of the electromagnetic spectrum (Figure 2). Additionally, the Themis Z TEM has a Super X EDX detector that delivers high signal to noise ratio for optimum EDX results. During my talk, I will be presenting different applications for each of these new capabilities, which are relevant to nanomaterials developed and studied in our institution.

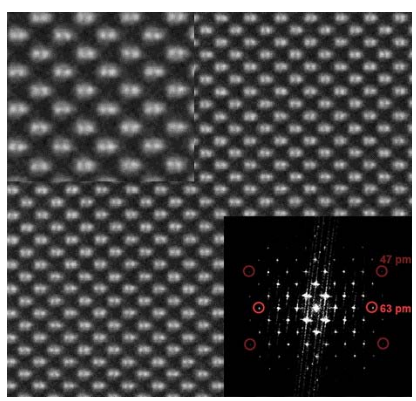


Figure 1. STEM image showing GaN [211] taken at 300kV and the corresponding FFT showing dumbbell resolution of 63 pm

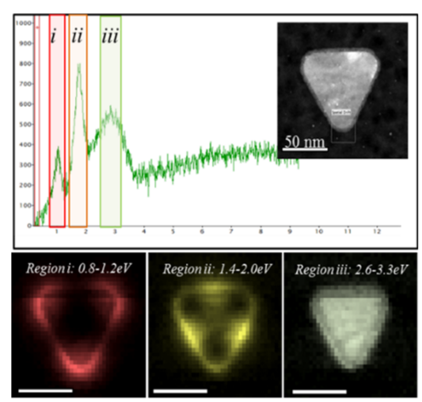


Figure 2. High-resolution EELS (top) and reconstructed plasmon maps (bottom) of 65nm Ag-SiO2 plates (top inlet). LSP excitation from corners (i), sides (ii), and core plasmon (iii).

Chemical and Electronic Properties of Solid Surfaces

Dmitry Zemlyanov

Senior Research Scientist - Surface Science Application

Birck Nanotechnology Center, Purdue University

Dmitry Zemlyanov received his Ph.D. in Physics and Mathematics from the Novosibirsk State University, Russia, in 1995. He is currently a Senior Research Scientist - Surface Science Application at Birck Nanotechnology Center, Purdue University. He held research and teaching positions in premier scientific organizations in Russia, Ireland and Germany prior to joining Purdue and published over 140 journal papers in the areas of surface science, catalysis, pharmacy and materials science. At Purdue, he collaborates with a wide variety of research groups from College of Science and College of Engineering enabling them to develop and apply advanced scientific instrumentation in the area of surface characterization.

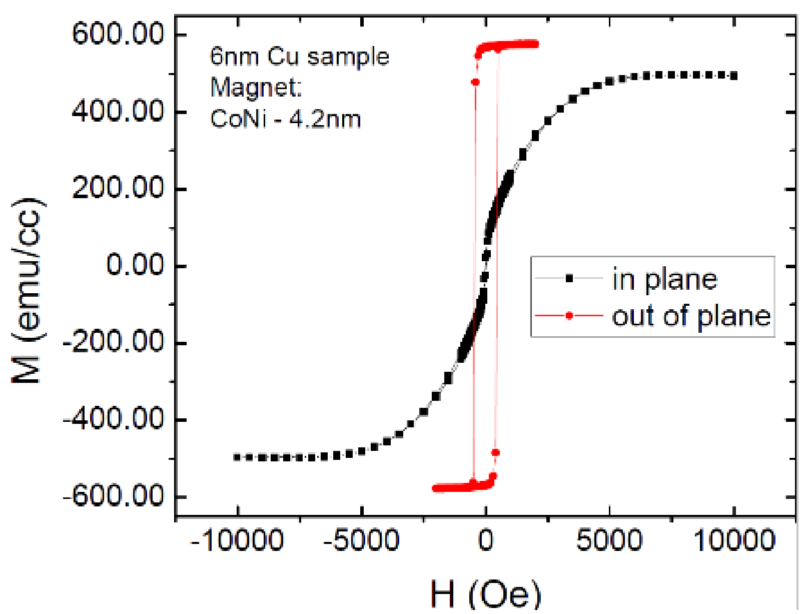
Material characterization is an important aspect for various applications. In particularly, for 2D materials and nano-materials, the surface characterization becomes crucial for smart material design, functionalization, fabrication, etc. Surface Analysis Facility at Birck Nanotechnology Center, Purdue University, is equipped with state-of-art analytical equipment, which can greatly benefit many researchers from Schools of Engineering and Colleges of Science. I would like to demonstrate examples of the studies using X-ray photoelectron spectroscopy (XPS), scanning tunneling microscopy/spectroscopy (STM), high–resolution electron energy loss spectroscopy (HREELS), low energy electron diffraction (LEED). The applications of these techniques will be represented for the studies of 2D materials and thin films (graphene, phosphorene, BN, MoS_2), atomic layer deposition, pharmaceutical compounds and biologically-inspired surfaces.

Neil Dilley

Neil Dilley is a physicist specializing in cryogenic measurements and design. His doctorate work at UC San Diego (Ph.D. 1999) focused on sythesis and characterization of rare earth intermetallic compounds which exhibit superconductivity and magnetism. Neil's current research interests are in magnetic materials discovery, spintronics, and nanomagnetism. He joined Birck after working for 16 years at Quantum Design, Inc. in both R&D and applications where he instructed and collaborated with materials researchers around the world.

Materials Characterization at high magnetic fields and extreme temperatures, with a focus on magnetism

Recent additions to the recharge center at the Birck Nanotechnology Center in Purdue's Discovery Park include an **MPMS-3** SQUID magnetometer and a **DynaCool** Physical Properties Measurement System from Quantum Design. The **MPMS-3** measures the DC and AC magnetic moment of bulk, film or powder samples from 1.8 K – 1000 K and in applied fields up to 7 tesla. The system is also capable of simultaneous electrical excitation for magnetoelectric (multiferroic) investigations. Powered by a SQUID, it can achieve better than 10^{-8} emu sensitivity which enables quantitative studies of ultrathin (<1 nm) films of magnetic materials. Magnetic anisotropy measurements are one common application for the MPMS-3 (see figure).
The **DynaCool** measures electrical, magnetic and thermal properties of samples down to 1.8 K and in applied fields up to 9 tesla. Being a general field/temperature platform, it is capable of adding customized probes, optical and RF measurements. The most popular measurement for the user group is magnetotransport (Hall effect, magneto-resistance) of magnetic films and devices, sometimes utilizing the automated sample rotation insert. After reivewing the capabilities of the instruments, I will highlight some research results on both instruments including voltage-controlled magnetic anisotropy, ferromagnetic resonance (FMR) spectroscopy, and finally magnetotransport with a look ahead to new high-sensitivity electronics for carrier mobility detemination in low mobility systems.



Birck Optics and Spectroscopy Lab / Optics recharge Center, recent updates

Alexei Lagoutchev, Simeon Bogdanov, Harshavardhanareddy Eragamreddy, Clayton Devault, Deesha Shah. Alexandra Boltasseva, Vladimir Shalaev

Presented are the recent developments in device park and new capabilities, in particular ellipsometry measurements at temperatures up to 1000 deg. C, new powerful kilohertz femtosecond laser system, fluorescence lifetime measurement system / AFM setup, lamellar NIR-MidIR Fourier spectrometer, IR fluorescent measurement setup. As applications examples, first ever optical constants measurements of Titanium Nitride at elevated temperatures, fast pump-probe measurements of transparent conducting oxide films, plasmonic enhancement of single photon emission from nitrogen vacancy centers in nanodiamonds and brightest ever achieved emission from such centers are going to be presented. Few other projects and future plans are to be briefly discussed in the end.

Alexei Lagoutchev, Senior Research Scientist.

Born 1959, BS (1980), MS (1982) in Physics from Moscow State University, Physics Department; PhD (1992) in Physics/Math from Institute of General Physics, Russian Academy of Sciences. Work history: Institute of General Physics, Moscow - trainee, junior/senior research associate, Institute of Atomic and Molecular Sciences, Academia Sinica, Taiwan - postdoc, University of Illinois at Urbana-Champaign – Research Associate. Areas of expertise: computer simulation of laser beam propagation in the atmosphere in the presence of random wind; Experimental laser-assisted isotopic gas mixture separation in capillaries, tunable CO2 and CO laser design, mass-spectroscopic monitoring of gas flows, vacuum cell design, gas flow simulations.; Experimental picosecond sum-frequency generation spectroscopy studies. Picosecond laser and OPA installation design and maintenance. Modelling molecular vibrations with Gaussian package.; Experimental femtosecond sum-frequency generation (SFG) spectroscopy of laser-generated shock waves in pump-probe configuraton, spectroscopical and electrochemical cell design, Ti:Sapphire, OPA and SFG femtosecond pump-probe installation design (commercialized) and maintenance. ; Femtosecond pump-probe, Z-scan, Fluorescence Lifetime Imaging, Time-Correllated Single Photon Counting, studies of single photon emitters, Raman spectroscopy, Near Field Optical Microscopy.

Married with one son, hobbies: competitive sailing, cross-country skiing, cycling.