MATERIALS DAY 2019

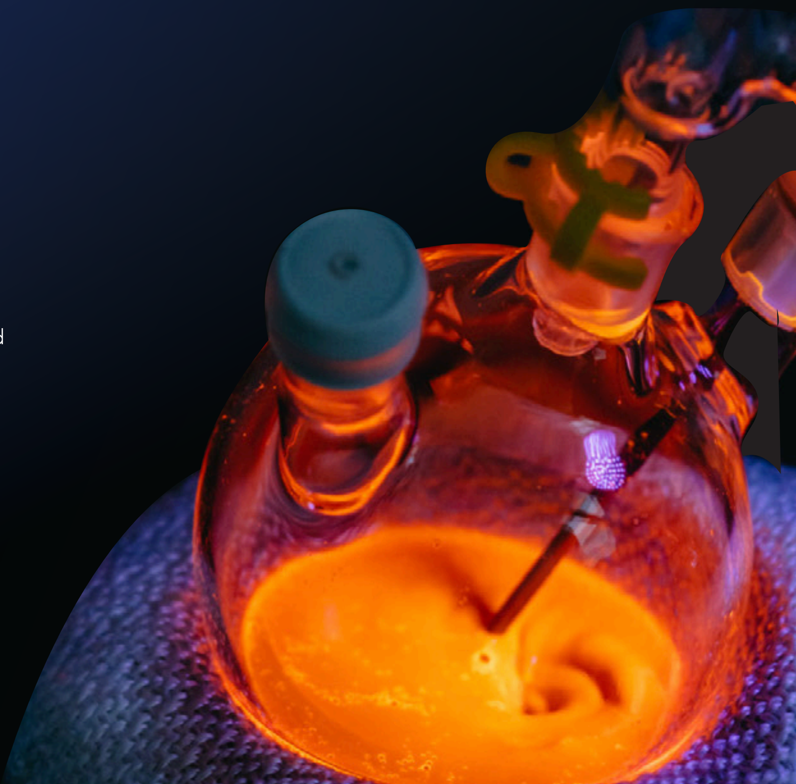
DIVISION OF MATERIALS SCIENCE & ENGINEERING

(NANO)MATERIALS

FOR BIOSENSING AND DIAGNOSTICS

BU.EDU/ENG/MATERIALSDAY2019

Boston University
Photonics Center
September 27, 2019



The Materials Day 2019 feature photo is provided by the Photonics Center.

BOSTON UNIVERSITY

(NANO)MATERIALS FOR BIOSENSING AND DIAGNOSTICS: Novel materials development in fluorescent and plasmonic nanoparticles, anti-fouling surfaces, and textile electronics are helping to propel innovations in personal health, wellness monitoring, and cell phone-based diagnostic tools. Eminent scholars will present on recent advances that are part of a movement to reshape the information each of us has regarding our own health and wellness. **HOSTED BY ASSISTANT PROFESSOR ALLISON DENNIS (BME, MSE).**

AGENDA

8:15 AM	**REGISTRATION AND CONTINENTAL BREAKFAST** 9th Floor East End Lounge
8:45 AM	**WELCOME** | Kenneth Lutchen, Dean, College of Engineering and Gloria Waters, Vice President and Associate Provost for Research
9:00 AM	**HADI SHAFIEE, BRIGHAM AND WOMEN'S HOSPITAL** Mobile Health Diagnostics with Applications in Medicine
9:45 AM	**ALLISON DENNIS, BOSTON UNIVERSITY** Engineering Semiconductor Quantum Dots for Biosensing Applications
10:30 AM	**MORNING COFFEE BREAK** 9th Floor East End Lounge
10:45 AM	**RUSS ALGAR, UNIVERSITY OF BRITISH COLUMBIA** Not Everybody Dyes: Leveraging Quantum Dots and Other Luminescent Nanomaterials for New Opportunities in Bioanalysis
11:30 AM	**HEATHER CLARK, NORTHEASTERN UNIVERSITY** Nanosensors for Chemical Imaging of Acetylcholine in the Brain using MRI
12:15 PM	**LUNCH BUFFET** 9th Floor East End Lounge
12:50 PM	**LUNCH SPEAKER: SAMIR MITRAGOTRI, HARVARD UNIVERSITY** Clinical Translation of Nanoparticles: Hurdles and Opportunities
1:35 PM	**HADLEY SIKES, MASSACHUSETTS INSTITUTE OF TECHNOLOGY** A Materials Approach to More Effective Immunoassays
2:20 PM	**AFTERNOON COFFEE BREAK** 9th Floor East End Lounge
2:30 PM	**NIKO HILDEBRANDT, UNIVERSITÉ DE ROUEN AND UNIVERSITÉ PARIS-SACLAY** Multiplexed Time-Gated FRET Biosensing and Diagnostics Using Quantum Dots, Lanthanides, and Dyes
3:15 PM	**TRISHA ANDREW, UNIVERSITY OF MASSACHUSETTS, AMHERST** Sensing Human Behavior with Smart Garments
4-5:30 PM	**POSTER SESSION | WINE & CHEESE RECEPTION** 7th Floor Atrium

RUSS ALGAR

University of British Columbia

Associate Professor, Michael Smith Foundation for Health Research Scholar, Canada Research Chair in Bio/Chemical Sensing

NOT EVERYBODY DYES: LEVERAGING QUANTUM DOTS AND OTHER LUMINESCENT NANOMATERIALS FOR NEW OPPORTUNITIES IN BIOANALYSIS

ABSTRACT: Fluorescent dyes and proteins are great—except when they're not. Colloidal semiconductor quantum dots (QDs) are excellent alternatives for fluorescent dyes—except when they're not. With the wide and growing variety of luminescent materials available, no single material is best-suited to every application. This presentation will overview our research in developing methods of bioanalysis that leverage QDs and other luminescent nanomaterials to achieve capabilities that are both suited to the nanomaterial and not possible with fluorescent dyes or proteins alone. These include smartphone-based platforms for biomolecular and cell-based assays, as well as single-vector multiplexed concentric FRET probes toward cellular sensing. Special attention will be paid to our ongoing development of multifunctional composites of QDs and other nanoparticle materials. The optical properties of these composites overcome the deficiencies of a smartphone for fluorescence measurements without requiring sophisticated engineering. With the composite nanoparticles and a simple 3D-printed device, we are able to isolate and count HER2-positive cancer cells against a background of HER2-negative cells. This work is now moving toward barcoded assays for multiplexed cell detection, cell-surface antigen profiling, and single-analyte detection on a smartphone. A primary goal of our research is to develop materials and devices that make molecular medicine more accessible, whether at the bedside or in remote or low-resource settings.

BIO: W. Russ Algar is an Associate Professor in the Department of Chemistry at the University of British Columbia, a Canada Research Chair (Tier 2) in Bio/Chemical Sensing, and a Michael Smith Foundation for Health Research Scholar. Algar received his Ph.D. from the University of Toronto in 2010 and was a postdoctoral fellow at the U.S. Naval Research Laboratory before moving to UBC in 2012. His research focuses on the applications of luminescent materials in bioanalysis, including point-of-care diagnostic technologies, multifunctional probes, molecular photonic logic, and fundamental spectroscopy, biophysical chemistry and bioconjugate methods to support these applications. Algar has published more than 85 papers, collectively cited more than 4600 times. He was won several awards, including an Alfred P. Sloan Fellowship, the Canadian Society for Chemistry Beamish Award, the Emerging Leader in Molecular Spectroscopy Award, and was named one of the Top 40 Under 40 in analytical science.

TRISHA ANDREW

University of Massachusetts, Amherst

Associate Professor of Chemistry and Chemical Engineering
Director, Wearable Electronics Lab

SENSING HUMAN BEHAVIOR WITH SMART GARMENTS

ABSTRACT: Smart apparel with embedded self-powered sensors can revolutionize human behavior monitoring by leveraging everyday clothing as the sensing substrate. The key is to inconspicuously integrate sensing elements and portable power sources into garments while maintaining the weight, feel, comfort, function and ruggedness of familiar clothes and fabrics. We use reactive vapor coating to transform commonly-available, mass-produced fabrics, threads or premade garments into a plethora of comfortably-wearable electronic devices by directly coating them with uniform and conformal films of electronically-active conjugated polymers. By carefully choosing the repeat unit structure of the polymer coating, we access a number of fiber- or fabric-based circuit components, including resistors, depletion-mode transistors, diodes, thermistors, and pseudocapacitors. Further, vapor-deposited electronic polymer films are notably wash- and wear-stable and withstand mechanically-demanding textile manufacturing routines, enabling us to use sewing, weaving, knitting or embroidery procedures to create self-powered garment sensors. We will describe our efforts in monitoring hear trate, breathing, joint motion/flexibility, gait and sleep posture using loose electronic garments and highlight collaborative endeavors to combine signal processing, machine learning and human factor integration to predict behavior in selected at-risk populations.

BIO: Trisha L. Andrew is an Associate Professor of Chemistry and Chemical Engineering at the University of Massachusetts Amherst. She directs the Wearable Electronics Lab, a multi-disciplinary research team that produces garment-integrated technologies using reactive vapor deposition. Trisha started her career as an Assistant Professor of Chemistry and Electrical Engineering at the University of Wisconsin-Madison, after receiving her Ph.D. from MIT in 2011. She is a David and Lucile Packard Foundation Fellow, a National Academy of Sciences Kavli Fellow, a L'Oréal USA For Women in Science Fellow, and was named as one Forbes' magazine "30 Under 30" Innovators in Energy.

HEATHER CLARK

Northeastern University

Professor of Bioengineering, Chemistry and Chemical Biology

NANOSENSORS FOR CHEMICAL IMAGING OF ACETYLCHOLINE IN THE BRAIN USING MRI

ABSTRACT: New tools have the potential to unlock unexpected insights into biology. We are extending the toolbox for imaging the dynamic processes of the brain and body by developing an array of nanosensors for the measurement of ions and small molecules. Our particle-based sensors are easily tunable for dynamic range and extendable to new analytes, such as sodium, chloride, glucose, and neurotransmitters. We work with a variety of imaging modalities in order to overcome the challenges of deep-tissue imaging. In this presentation, I will discuss the fabrication and analytical characteristics of sensors designed to detect acetylcholine in the brain using MRI. The nanosensor is composed of acetylcholine-catalyzing enzymes and pH-sensitive gadolinium contrast agents co-localized onto the surface of polymer nanoparticles which leads to changes in T1 relaxation rate (1/T1). The mechanism of the sensor involves the enzymatic hydrolysis of acetylcholine leading to a localized decrease in pH which is detected by the pH-sensitive gadolinium chelate. The concomitant change in 1/T1 in vitro measured a 20% increase from 0 to 10 micromolar acetylcholine concentration. The applicability of the nanosensors in vivo was demonstrated in the rat medial prefrontal cortex (mPFC) showing distinct changes in 1/T1 induced by pharmacological stimuli. The highly-specific acetylcholine nanosensor we present here offers a promising strategy for detection of cholinergic neurotransmission and will facilitate our understanding of brain function through chemical imaging.

BIO: Heather Clark is a Professor in the Departments of Bioengineering and Chemistry at Northeastern University. In addition, she is the Founding Director of the Institute for Chemical Imaging of Living Systems and an Associate Editor at ACS Sensors. She received her PhD in Analytical Chemistry from the University of Michigan, and completed a postdoc in the Center for Cell Analysis & Modeling at the University of Connecticut Health Center. Dr. Clark's research focuses on the development of nanosensors to measure concentrations of ions and small molecules at the cellular level, as well as in vivo. She has received awards for both research and teaching, including the DARPA Young Faculty Award. Her work has been featured in a live CNN interview, the Wall Street Journal, WIRED magazine and MIT Technology Review.

ALLISON DENNIS

Boston University

Assistant Professor of Biomedical Engineering and Materials Science and Engineering

ENGINEERING SEMICONDUCTOR QUANTUM DOTS FOR BIOSENSING APPLICATIONS

ABSTRACT: Semiconductor quantum dots (QDs) act as exceptionally bright photoluminescent beacons in biosensing applications. We build on core/shell material structures and their well-studied emission tuning to focus on biosensing applications through enhancement of the nanoparticle absorption cross-sections. Through absorption tuning of indium phosphide QDs, we have generated multiple colors of cadmium-free, brightness-matched QDs and studied the impact of QD shell thickness on Förster resonance energy transfer (FRET), including QD-QD FRET. Two sensor constructs enable the transduction of differential analyte binding by allosteric transcription factors (aTFs) into fluorescent outputs to quantify nanomolar concentrations of the model analyte. In one design, FRET between a QD and organic dye produces a ratiometric signal based on a change in distance between the analyte-bound and -unbound states. In a second design, the localization (or lack thereof) of QDs on the surface of a bead substrate depends on the presence or absence of the small molecule analyte. The change in spatial localization of the bright QD signal is easily discerned by eye and through analysis of digital images captured on a cell phone camera, enabling the sensitive detection of a small molecule without antibodies or expensive analytical instrumentation. Continued development of QDs and QD coatings for specific biosensing applications ensures that we are using the best nanomaterials for a given purpose.

BIO: Professor Allison Dennis is an assistant professor in the Department of Biomedical Engineering and Division of Materials Science and Engineering at Boston University. Her research group use materials design principles to develop semiconductor nanoparticles for specific applications in biosensing and biomedical imaging. Prof. Dennis has secured multiple fellowships and awards including a Fulbright Scholar Award, National Defense Science and Engineering Graduate Fellowship, Ocean Optics Young Investigator Award, and a KL2 Faculty Training Fellowship. The Dennis Lab appreciates past and current support from intramural and extramural sources including DARPA, NSF, NIH, and the BU Clinical and Translational Science Institute.

NIKO HILDEBRANDT

Université de Rouen and Université Paris-Saclay

Professor

MULTIPLEXED TIME-GATED FRET BIOSENSING AND DIAGNOSTICS USING QUANTUM DOTS, LANTHANIDES, AND DYES

ABSTRACT: Determination of biomolecular recognition via Förster Resonance Energy Transfer (FRET) plays an important role for quantifying concentrations and distances in many fields of the life sciences. Application of time-gated photoluminescence spectroscopy and microscopy for the analysis of FRET systems offers several advantages concerning versatility, sensitivity, and specificity. Luminescent lanthanide complexes exhibit extremely long luminescence lifetimes and multiple narrow emission peaks over a broad spectral range. These photophysical features make them highly interesting FRET donors in combination with different FRET acceptors, such as organic dyes or semiconductor quantum dots. Such FRET pairs have been successfully used for spectral and temporal multiplexing and highly sensitive detection of protein, peptide, DNA, and RNA biomarkers.

The presentation will give an introduction to time-resolved and time-gated FRET and explain the specific benefits of lanthanide/dye/quantum dot FRET pairs for spectral and temporal multiplexed luminescence detection. Then, recent applications of these FRET pairs in different homogeneous single-step FRET biosensors for the sensitive and specific detection of multiple biomarkers from low-volume liquid samples or on cell membranes and inside cells will be discussed. These nanoFRET biosensors provide a rapid, simple, selective, and sensitive tool for multiplexed detection of various oligonucleotides or proteins, which makes them highly interesting for clinical diagnostics and other biosensing applications.

BIO: Niko Hildebrandt is head of the FRET group (www.nanofret.com) at the Laboratoire de Chimie Organique, Bioorganique, Réactivité et Analyse (COBRA) in Rouen (Normandie, France). He holds a diploma in Medical Physics (2001, TFH Berlin, Germany) and a Ph.D. in Physical Chemistry (2007, University of Potsdam, Germany). After a short postdoc in 2007/2008 he was group leader at the Fraunhofer Institute for Applied Polymer Research (IAP) in Potsdam until 2010.

Since 2010 Dr. Hildebrandt has been Full Professor at Université Paris-Sud and from 2014 to 2019 a member of the Institut Universitaire de France (IUF). He was leading the NanoBioPhotonics group at the Institute for Fundamental Electronics (IEF, 2010 to 2016) and the Institute for Integrative Biology of the Cell (I2BC, 2016 to 2019) in Orsay (France). Niko's main research interest is time-resolved and time-gated Förster resonance energy transfer (FRET) spectroscopy and microscopy and the application of lanthanides and nanomaterials for multiplexed FRET biosensing.

He has contributed pioneering work to energy transfer between lanthanides and quantum dots and has coauthored more than 80 peer-reviewed papers, 6 book chapters, and 6 patents (H-index 33, >4500 citations). He is an editorial board member of Microchimica Acta, Methods and Applications in Fluorescence, Sensors, and Chemosensors and co-editor of the book FRET – Förster Resonance Energy Transfer: From Theory to Applications.

SAMIR MITRAGOTRI

Harvard University

Hiller Professor of Bioengineering and Hansjorg Wyss Professor of Biologically Inspired Engineering

CLINICAL TRANSLATION OF NANOPARTICLES: HURDLES AND OPPORTUNITIES

ABSTRACT: Nanoparticle-based diagnostic and drug delivery systems for systemic applications have significant advantages over their non-formulated and free drug counterparts. For example, nanoparticle systems are capable of targeting and treating areas of the body that other systems cannot reach. As such, nanoparticle drug delivery and imaging systems are one of the most investigated systems in preclinical and clinical settings. I will highlight the diversity of nanoparticle types, the key advantages these systems have over their free drug counterparts, and discuss their overall potential in influencing clinical care. I will discuss biological and technological challenges that impact the clinical success of nanoparticle delivery systems.

BIO: Samir Mitragotri is the Hiller Professor of Bioengineering and Wyss Professor of Biologically Inspired Engineering at Harvard University. Prior to this, he was the Mellichamp Chair Professor in the Department of Chemical Engineering at the University of California, Santa Barbara. His research is focused on transdermal, oral, and targeted drug delivery systems. He is an elected member of the National Academy of Engineering, National Academy of Medicine and National Academy of Inventors. He is also a foreign member of Indian National Academy of Engineering. He is also an elected fellow of AAAS, CRS, BMES, AIMBE, and AAPS. He is an author of over 280 publications, an inventor on over 180 patent/patent applications, and a Thomson Reuters Highly Cited Researcher. He received his BS in Chemical Engineering from the Institute of Chemical Technology, India and a PhD in Chemical Engineering from the Massachusetts Institute of Technology. He is the Editor-in-Chief of AIChE's and SBE's journal Bioengineering and Translational Medicine.

HADI SHAFIEE

Brigham and Women's Hospital

Assistant Professor of Medicine

MOBILE HEALTH DIAGNOSTICS WITH APPLICATIONS IN MEDICINE

ABSTRACT: The advances in micro- and nano-technologies and the surge in consumer electronics have paved a solid foundation for developing mobile health (mhealth) technologies with the potential to transform the current paradigm in global health. In this talk, Dr. Shafiee will present examples of how smart phones can be seamlessly integrated with hardware, software, microfluidics, and nanotechnology to develop point-of-care diagnostic devices to address clinical gaps in the management of infectious diseases and infertility.

BIO: Dr. Hadi Shafiee is an Assistant Professor at the Division of Engineering in Medicine at Brigham and Women's Hospital (BWH), Harvard Medical School (HMS). He graduated from Isfahan University of Technology, Iran (BSc) in 2001 and University of Tehran, Iran (MSc) in 2003 with degrees in Mechanical Engineering. He received his Ph.D. in Biomedical Engineering and Mechanics from Virginia Polytechnique Institute and State University in 2010. After receiving trainings in the development of devices for cell sorting and pathogen detection at Virginia Tech and Harvard-MIT Division of Health Science and Technology, he started his own lab at BWH, HMS in 2014. Dr. Shafiee's lab strives to develop innovative diagnostic tools to address unmet clinical challenges through integrating biology/medicine, micro- and nanotechnology, consumer electronics, and artificial intelligence. His work has been recognized by some of the major news outlets including CNN, the Guardian, Boston Globe, CBS News, STAT, New York Times, etc. He has mentored more than 60 postdoctoral research fellows, and undergraduate and graduate students. With an emphasis on translational research, he hopes to train the next generation of bioengineers and scientists to work at the forefront of bioengineering and regenerative medicine, and to expand the boundaries of this exciting field.

HADLEY SIKES

Massachusetts Institute of Technology

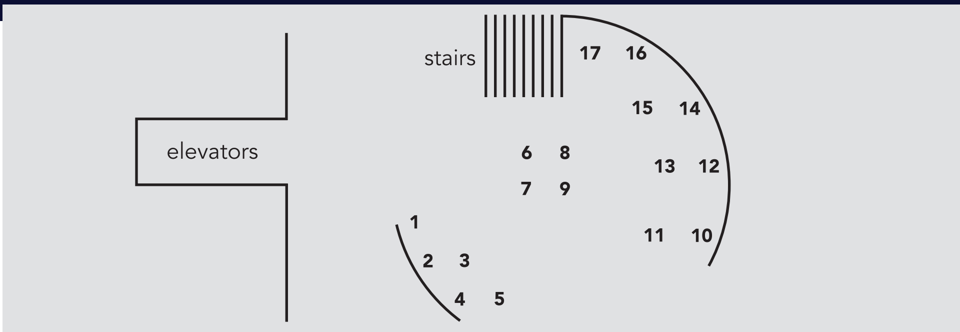
Esther and Harold E. Edgerton Associate Professor

A MATERIALS APPROACH TO MORE EFFECTIVE IMMUNOASSAYS

ABSTRACT: Our understanding of disease states, both communicable and non-communicable, progresses at a remarkable pace in this age of data-rich biology. Unfortunately, our current ability to make use of this knowledge on a routine basis in clinical settings is limited. The focus of this presentation will be to present examples of how engineering design and biomolecular engineering can be used to further the goal of improved access to the benefits of knowledge of disease at the molecular level. Different clinical settings and different diseases present differing needs, resources and challenges. For example, infectious diseases worldwide are either undiagnosed or incorrectly diagnosed at a staggering rate because diagnostic techniques that are feasible in the US are not feasible worldwide. An analysis of this problem will be presented along with two molecular technologies that my lab has developed for the detection of proteins in blood. Engineered binding proteins for sample capture and photo-redox catalyzed polymerization reactions for colorimetric signal amplification will be demonstrated to simultaneously meet performance metrics while also meeting practical constraints set forth by the World Health Organization.

BIO: Hadley D. Sikes is the Esther and Harold E. Edgerton Associate Professor of Chemical Engineering at the Massachusetts Institute of Technology. She leads a team of researchers in the application of physical principles to design, synthesize, characterize and test molecules for utility in detecting and understanding disease. Hadley earned a BS at Tulane University, a PhD at Stanford University, and was a postdoctoral scholar at the University of Colorado, Boulder, and the California Institute of Technology prior to joining the faculty at MIT.

POSTER SESSION



POSTER 1 Wenhan Cao
Institution: BU, ME
Advisor: Keith Brown
Title: Measuring Nanoparticle Polarizability Using Fluorescence Microscopy

POSTER 2 Fulya Ekiz Kanik
Institution: BU, ECE
Advisor: Selim Ünlü
Title: Development of Single-Molecule Counting Assays for Rare Mutation and Ultrasensitive RNA Biomarker Detection

POSTER 3 Celalettin Yurdakul
Institution: BU, ECE
Advisor: Selim Ünlü
Title: High-Throughput and Label-Free Imaging of Individual Biological Nanoparticles at High-Resolution

POSTER 4 Katherine Cook
Institution: BU, CHEM
Advisor: Mark Grinstaff
Title: Control Of Hydrogel Swelling And Mechanical Properties By Inserting Methylene Groups Into Crosslinkers For Optimal Burn Wound Dressings And Tissue Oxygenation Mapping

POSTER 5 Zhuofa Chen
Institution: BU, ECE
Advisor: Anna Swan
Title: Characterizing the Low Doping Regime and Charge Fluctuation in Graphene Using Raman Spectroscopy

POSTER 6 Andrew Martin
Institution: BU, BME
Advisor: Mark Grinstaff and Xue Han
Title: Polymeric Nanoparticle Degradation Acidifies Lysosomes and Mitigates Mitochondrial Dysfunction

POSTER 7 Mingfu Chen
Institution: BU, BME
Advisor: Mark Grinstaff
Title: Solid-Phase Antibiotic Biosensor

POSTER 8 Karthika Sankar
Institution: BU, MSE
Advisor: Mark Grinstaff
Title: Electrochemical Assay for Progesterone

POSTER 9 Ran Cheng
Institution: BU, CHEM
Advisor: Chen Yang
Title: Optoacoustic Neurostimulation by Carbon Nanotubes

POSTER 10 Siyang Xiao
Institution: BU, ME
Advisor: Chuanhua Duan
Title: Water Evaporation from Graphene Nanopores

POSTER 11 Nan Zheng
Institution: BU, MSE
Advisor: Chen Yang
Title: Heterogeneous Innervated Bone Culture on Self-Folded Silk Rolls

POSTER 12 Zhancheng Yao
Institution: BU, MSE
Advisor: Anna Swan
Title: Micro-Raman Measurement of Strain in Silicon Nanowires

POSTER 13 Joshua Kays
Institution: BU, BME
Advisor: Allison Dennis
Title: Designing Quantum Dots for *In Vivo* Use: Copper Indium Sulfide as a Test Case

POSTER 14 Anisha Joenathan
Institution: BU, MSE
Advisor: Mark Grinstaff
Title: Evaluation of Tantalum Oxide Nanoparticles as a Theranostic Agent for Cartilage

POSTER 15 Alexander Saeboe
Institution: BU, MSE
Advisor: Allison Dennis
Title: Developing Tools for Fluorescent Dual Probe Imaging in the Near Infrared

POSTER 16 Linli Shi
Institution: BU, CHEM
Advisor: Chen Yang
Title: A Fiber-based Optoacoustic Emitter with Maximized Conversion Efficiency and Controlled Ultrasound Frequency for Biomedical Applications

POSTER 17 Panagis Samolis
Institution: BU, ECE
Advisor: Michelle Sander
Title: Phase-Sensitive Mid-Infrared Photothermal Imaging for Biological Applications

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2. Once connected, open your web browser and navigate to a new webpage. You will be redirected to a registration webpage.

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Elizabeth Flagg, Gabriella McNevin, Ruth Mason

WORKSHOP ORGANIZER ALLISON DENNIS would like to express warm gratitude to those who support the organization of Materials Day, and thank all who attend.