Program

2:30 – 3:00 pm Refreshments

3:00 – 3:15 pm MSE Mentor Appreciation Event

3:15 – 4:00 pm Keynote Address

Dr. Tia Benson Tolle, Director, Advanced Materials Product Development Boeing Commercial Airplanes, The Boeing Company

4:00 – 4:15 pm Break

Graduate student presentations

4:15 – 4:30 pm Adharsh Rajagopal
Development of Highly Efficient Perovskite-Perovskite Tandem Solar Cells

4:30 – 4:45 pm Richard Revia
Magnetic Nanoparticles for Targeted Theraonotics

4:45 – 5:00 pm Matthew Lim
Rapid, Solventless Approach to Tunable Carbons for Energy Storage

5:00 – 5:15 pm Richard Lee
Design and Implementation of Highly Versatile Peptide-Probe Modular Molecular Constructs for Bionanosensing with Single-Layer FETs

5:15 – 5:30 pm Break

5:30 – 5:35 pm Peter Pauzuskie
UW Molecular Engineering Materials Center

5:35 – 5:50 pm Wes Tatum
MANA-T: Predicting Device Scale Morphology and Performance

5:50 – 6:05 pm Yun Li
Ultra-High Power, Low Cost, & Rechargeable Zn Batteries for Large-Scale Stationary Grid Storage

6:05 – 6:20 pm Alex Stark
Characterizing the Reliability of Solid Oxide Fuel Cells Under Simulated Operation

6:20 – 6:35 pm Break. Room will be flipped so please briefly leave the room.

6:35 – 8:30 pm Poster, Meet and Greet with new chair Prof. Jihui Yang, networking, wine reception
Abstracts

Keynote
Tia Benson Tolle
Aerospace Materials: Challenges and Opportunities

Materials have enabled many of the breakthroughs that make our society thrive and grow. Today, we are in the era of 'engineered materials' - no longer reliant on discovery of a new material, increasingly able to design materials and matter specifically for products and their production. Implications of this trend will be discussed; challenges and opportunities in aerospace applications of materials presented; and an example of paths that a materials engineer can take as they cross from academia to industry will be shared.

Oral Presentations

1. Adharsh Rajagopal (Advisor: Alex Jen)
   Development of Highly Efficient Perovskite-Perovskite Tandem Solar Cells
   Co-author: Yang, Zhibin; Materials Science and Engineering, University of Washington

   Power conversion efficiencies (PCEs) for perovskite single junction solar cells are inching closer to the corresponding Shockley-Queisser limit. To further improve PCE, it is highly desirable to develop all perovskite tandem solar cells, which possess merits of solution processability and low-cost, large-scale manufacturing capability inherent to hybrid perovskites. However, severe photovoltage loss \( (V_{oc,loss} = E_g/q - V_{oc}) \) in individual subcells are currently limiting the performance of perovskite tandem solar cells.

   By utilizing an integrated process, compositional, interfacial, optical, and device engineering we successfully minimized the overall \( V_{oc,loss} \) and have achieved a record high PCE of 18.5% for monolithic (2-terminal) perovskite-perovskite tandem solar cells. Mitigation of non-radiative recombination centers arising from improper interfacial energetics and poor optoelectronic characteristics of absorber materials were pivotal in realization of enhanced quasi-fermi level splitting and thus improved open-circuit voltage \( (V_{oc}) \) for individual subcells. Ultimately, the tandem solar cell possesses a high \( V_{oc} \) of 1.98 V, which is approaching an impressive 80% of the theoretical limit and by far the best for all perovskite based monolithic tandem solar cells. The talk will be centered around this recent exciting development to highlight prospects of using perovskite-perovskite tandems for solar energy generation.

2. Richard Revia (Advisor: Miqin Zhang)
   Magnetic Nanoparticles for Targeted Theranostics

   Nanotechnology can directly address the many shortcomings of current clinical treatments for cancer. In an effort to develop better therapeutic and diagnostic, or so-called theranostic, capabilities in the fight against cancer, the Zhang group is actively
developing iron oxide nanoparticles for targeted drug delivery of chemotherapeutics, advanced imaging techniques, and radiotherapy enhancement. Iron oxide nanoparticles have distinct benefits over other nano-formulations due to their biocompatibility, biodegradability, ease of synthesis, and ability to be functionalized with targeting epitopes, chemotherapeutics, and molecular imaging probes. Our group has successfully delivered standard chemotherapeutic drugs to tumor sites in a targeted fashion, thereby increasing therapeutic efficacy while minimizing harmful side effects. We are also able to finely tune the properties of our nanoparticles to provide contrast in magnetic resonance imaging (MRI). When our advanced imaging platforms are combined with our targeted delivery mechanisms we can provide an unprecedented diagnostic tool for the early detection of cancer in a noninvasive fashion. Recent studies by our group have also shown that iron oxide nanoparticles can enhance conventional radiotherapy. Animal models bearing a highly invasive and lethal form of brain cancer were injected with iron oxide nanoparticles and then irradiated with a clinical dose of radiotherapy. These animals displayed a 2-fold increase in overall survival time compared to animals receiving only radiotherapy. Preliminary results on all of these fronts is highly encouraging and demonstrates that our nanoparticles can deliver therapeutics specifically to brain tumors, overcome drug resistance, and significantly extend survival in animal models. We are excited to continue this promising research and extend it towards clinical use in humans.

3. Mathew Lim (Advisor: Peter Pauzauskie)

*Rapid, Solventless Approach to Tunable Carbons for Energy Storage*

Co-author: Costantino, Henry R.; Group14 Technologies
Timmons, Christopher D.; Group14 Technologies
Sakshaug, Avery J.; Group14 Technologies
Dhanabalan, Abirami; Group14 Technologies
Feaver, Aaron M.; Group14 Technologies; EnerG2

High-surface-area, porous carbon materials comprising micro- and/or meso-pores (pore diameter <2 nm and 2–50 nm respectively) offer diverse applications in medicine, purification, and energy storage. Often, these carbons are produced by pyrolysis and activation of readily available organic matter such as coke, wood, or coconut shell, but it is difficult to tailor the pore structure and chemistry of the carbons with such starting materials. By using a synthetic organic resin as the precursor instead, one can adjust the synthetic parameters of the resin to optimize the properties of the final carbon. In this work, we present a rapid, scalable, and tunable route to porous carbons based on the solid-state polymerization of bisphenol A (BPA) with hexamethylenetetramine (HMT). Mixtures of BPA and HMT powder can be cured into a resin at mild temperatures in a matter of hours, followed by conversion into carbon using standard, scalable industrial processes. The final carbons feature surface area >1700 m2/g and pore volume >0.7 cm3/g with >20% yield for the process. This procedure is much simpler, faster, and more environmentally friendly than traditional wet chemistry approaches to resins, which require solvents, catalysts, stirring, and drying prior to carbonization. Furthermore, we show that adding a solid-state chemical activating agent to BPA and HMT gives higher
surface area and pore volume at lower carbonization times and temperatures. Beyond synthesis, we demonstrate the promising applications of these carbons as scaffolds to stabilize nanoscale silicon for lithium-ion battery anodes, and as electrodes for supercapacitors. Anodes made from incorporating silicon into our BPA–HMT carbon show a reversible capacity in excess of 1200 mAh/g when cycled against lithium, with <20% capacity fade even after 20 C/2 cycles. Supercapacitor electrodes made from our BPA–HMT carbons feature gravimetric capacitance >110 F/g and volumetric capacitance >25 F/cm3.

4. Richard Lee (Advisor: Mehmet Sarikaya)

*Design and Implementation of Highly Versatile Peptide-Probe Modular Molecular Constructs for Bionanosensing with Single-Layer FETs*

Hayamizu, Y.; Organic and Polymeric Materials, Tokyo Institute of Technology
Grady, W.; Clinical Research Division, Fred Hutchinson Cancer Research Center

Biosensor platforms show promise for early diagnosis of many types of cancers. A key challenge in designing biosensors, however, is achieving high detection sensitivity without compromising target specificity. Field effect transistors based on 2D solids offer enhanced sensitivity due to their atomically thin characteristics. Still, such biosensors must possess several critical attributes to detect ultra-low target concentrations within a bodily fluid: (1) Probes must be securely immobilized onto the 2D-layer substrate; (2) Optimal molecular packing of the probe must be controlled for efficient target capture; (3) Non-specific adsorption of molecules other than the target must be prevented; (4) Non-covalent attachment of the probe onto the surface is favored to avoid causing surface defects which would otherwise affect sensing properties. Achieving these attributes presents several major obstacles. Herein we developed a biosensor platform that addresses these challenges, and sets the foundation for further development of a versatile cancer diagnostic device. Here we use a mixed-monolayer of two graphene-binding peptides. One immobilizes probes onto the sensing surface and the other confers anti-fouling properties that mitigate non-specific protein adsorption. The probe immobilizing peptide is a modular chimeric construct and can be easily modified to detect various targets within complex biological mixtures. We show that specific biomarkers implicated in pancreatic cancer (CEA and CA19-9) were selectively detected in 10-8 g/mL range against a background of 3% fetal bovine serum. Additionally, the modular design was used to target microRNA biomarkers – with the eventual goal of collecting expression profiles for clinical diagnosis and prognosis of various diseases. In conclusion, we have developed a biosensing strategy for flexible target sensing of biomolecules which provides effective passivation of the sensing surface for highly-specific detection. The research was supported by NSF-MGI (Materials Genome Initiative) Program through DMR-1629071 and by the Amazon-Catalyst program through UW/CoMotion.
5. Peter Pauzauskie  
*UW Molecular Engineering Materials Center*

The University of Washington Molecular Engineering Materials Center (UW MEM-C) addresses fundamental problems in materials research that push the frontiers of science, accelerate the development of future advanced technologies, and address challenges of broad national and societal importance. MEM-C’s research activities stress innovation in the design, discovery, and application of complex electronic and photonic inorganic materials with low dimensionality. MEM-C also spearheads education, training, and outreach programs to prepare tomorrow’s leaders in science and technology, with signature programs focusing on promotion of (re)entry of veterans into science/technology/engineering/mathematics (STEM) career tracks, and early recruitment/mentorship of students to STEM from underrepresented/underserved regional high schools. Additional activities include REU/RET/REM programs, regional K-20 outreach, regional partnerships for public engagement, and interdisciplinary curriculum development. MEM-C further strengthens ties between UW and industrial, international, and National Laboratory partners through sponsored internships and collaborations. MEM-C shared facilities provide lasting infrastructure that promotes the activities of the Center as well as of the broader campus and regional materials science communities.

6. Wes Tatum (Advisor: Christine Luscombe)  
*MANA-T: Predicting Device Scale Morphology and Performance*

Organic electronics have rapidly improved by focusing on discovering and exploiting relationships between chemical structures and device performance. However, precise prediction of microstructure of these thin films has been largely neglected, despite being just as crucial for the final device properties. Many different factors influence the microstructure of thin-films such as the solution concentration, solubility, and annealing conditions. The objective of this project is to develop software that learns predictive relationships between processing conditions, the film’s morphology, and device performance. This software, known as “Morphological Analysis of Nanostructured Thin-films”, or MANA-T, achieves this through a simple, open-sourced method for classifying the polymer’s phase (e.g. amorphous, crystalline). These nanometer-scale classifications are based on spatial mapping of mechanical properties as determined by an atomic force microscopy (AFM) scan and a Python classifier. This classification methodology is easily applied to any thin-film where different phases display different mechanical properties. Once the classification process is externally verified by UV-vis spectroscopy and conductive AFM, a library of thin-film data that describes the MANA-T classified morphology and device-scale performance at different annealing times and temperatures will be subjected to two different machine learning methods, namely least absolute shrinkage and selection operator (LASSO) regression and convolutional neural networks (CNN). Once trained and validated on this library, the MANA-T software will have the
ability to predict a thin-film’s morphology and device performance based solely on its processing conditions, specifically annealing time and temperature.

7. Yun Li (Advisor: Jihui Yang)
Ultra-High Power, Low Cost, & Rechargeable Zn Batteries for Large-Scale Stationary Grid Storage

Large-scale stationary grid storage technology with low-cost, long-life, and high power capability is essential to manage peak energy demands, improve grid reliability, and integrate renewable energy sources. Rechargeable aqueous Zn-ion batteries (ZIB) are very promising for large-scale stationary grid storage owing to their low-cost, environmentally benign constituent elements, excellent safety, and relatively high-energy density. Their application, however, is largely limited by the low cyclability and low power capability of the current cathode materials, predominately being the polymorphs of MnO2. The controversy and ambiguity of the reaction mechanisms in the Zn/MnO2 system impede further improvement of its cycling stability and power capability. In this work, for the first time, by combining experimental and theoretical efforts, a combination of H+/Zn2+ intercalation and conversion reactions occurring at different voltages was uncovered in this system, and the rapid capacity fading was unambiguously ascribed to the rate-limiting conversion reactions at a lower voltage. Through rational mitigation of the irreversible conversion reactions, we successfully established ultra-high power and long-life Zn/MnO2 cells which, after 1000 cycles, maintain an energy density of ~ 231 Wh kg⁻¹ at a power density of ~ 4 kW kg⁻¹ (9C, ~3.1 A g⁻¹) and an energy density of ~ 105 Wh kg⁻¹ at a power density of ~ 15 kW kg⁻¹ (30 C, ~10.3 A g⁻¹). The excellent cycling stability and power capability are superior to most reported ZIB or even those of lithium-ion batteries.

8. Alex Stark (Advisor: Dwayne Arola)
Characterizing the Reliability of Solid Oxide Fuel Cells Under Simulated Operation

Solid oxide fuel cells (SOFCs) are one of the most promising candidates for generating renewable clean energy in the next several years. To achieve high degrees of efficiency, the systems must operate at temperatures ranging from roughly 500-1000°C, and within a fuel environment containing various species including oxygen and hydrogen. These conditions have the potential to cause degradation in the ceramic cells, which can reduce their durability and lifespan. In addition, flaws resulting from the manufacturing process, or that are introduced during handling and assembly, can cause a reduction in the strength of the cells and their reliability. To design viable commercial fuel cell assemblies, a comprehensive understanding of the mechanical behavior of the cells under the operating conditions is critical, and a qualification of the vendor components is essential. In this investigation, the strength distributions for dense and porous magnesia magnesium aluminate (MMA) candidate cell materials are evaluated under a range of environments. The slow crack growth behavior was characterized, as well as a fractographic analysis was performed on the component fracture surfaces to identify the
It was found that the MMA exhibits a Weibull modulus of approximately 20 and the strength exhibits very limited rate dependence, indicating low susceptibility to failures attributed to slow crack growth. However, failures often initiated at surface pores that were introduced by the manufacturing process, which could be the limiting factor in commercial systems.

Poster Presentations

1. Chengfeng Du (Advisor: Xiaodong Xu)

   *Large-Scale Electrically Tunable Localized Quantum Emitter Arrays in MoSe$_2$/WSe$_2$ Heterostructures*

Layered materials (LMs) offer great opportunities for next-generation photonic and optoelectronic technologies such as lasers, modulators and photodetectors and are compatible with the silicon platform. However, quantum emitters in layered materials suffer from uncontrolled and uncertain origins, most of them are related to defects and strain gradients. Then in 2016, researchers from Cavendish Laboratory realized large-scale quantum emitter arrays by transferring WS$_2$ and WSe$_2$ monolayers onto prepatterned silicon substrate, generating large-scale quantum emitters arrays, thus solving scalability challenge in these layered materials-based quantum photonic devices. In our work, we aim to pattern 90nm SiO$_2$ pillar substrates using electron beam lithography technique and transfer monolayer MoSe$_2$/WSe$_2$ heterostructures onto these pillars to generate large scale localized interlayer exciton quantum emitters. What’s more, electrodes will be added to apply electric field and tune and control these quantum emitters, which would pave the way further for on-chip and electrically driven photon sources in two-dimensional semiconductors for quantum technology applications.

2. Sean Ghods (Advisor: Dwayne Arola)

   *Importance of inter-fibril bonding to the dynamic response of natural composites*

Fish scales are a natural biological composite that serve as a flexible armor. Each scale is essentially a laminate of unidirectional type I collagen fibril plies arranged in a bouligand stacking sequence. In this investigation, the dynamic loading response of fish scales was evaluated in uniaxial tension and transverse puncture to evaluated the importance of intermolecular bonding to the resistance to failure. Both loading formats were performed on scales fully hydrated (water) or after dehydration with a polar solvent (ethanol) to initiate intermolecular hydrogen bonding. The scales underwent a significant increase in the resistance to failure with loading rate, with average strain rate sensitivity exponents for the hydrated condition of 0.10 and 0.35 in tension and puncture, respectively. Exposure to the polar solvent did not substantially increase the rate sensitivity, but did increase the resistance to puncture. Exposure to the polar solvent increased the resistance to puncture of scales by as much as a factor of 7 with respect to the performance under fully hydrated conditions, and with a decreased damaged zone. In comparison, the increase in puncture resistance achieved with greater degree of mineral reinforcement was less substantial. Results demonstrate that interpeptide bonds are key
to the dynamic response of fish scales and that intermolecular bonding should be exploited in the design of new bioinspired materials for impact and penetration resistance.

3. **Sarah Holliday (Advisor: Christine Luscombe)**
   
   *Designing Solvent Systems for Improved Stability in Organic Solar Cells*

   Organic solar cells are one emerging technology that has the potential to substantially reduce the cost of solar energy production due to the use of earth-abundant materials and compatibility with high throughput, roll-to-roll printing techniques. A large amount of research has focused on increasing the efficiency of these devices by developing new organic polymers, leading to efficiencies that are now competitive with amorphous silicon. However, the lifetime of these organic solar cells is much shorter which is partly due to polymer photooxidation. Here we show that two important factors contributing to this degradation include i) the chemical structure of the polymer, which affects its photochemical stability, and ii) the use of high boiling point solvent additives during device printing, which can remain in the film after fabrication and facilitate the diffusion of oxygen into the film. An alternative solvent system is proposed here based on a low boiling point additive, which offers high efficiency and greatly enhanced stability, as well as being less environmentally hazardous relative to the traditional solvent systems.

4. **Anqi Lin (Advisor: Dwayne Arola)**
   
   *Blue Fin body armors: Inspired by natural composites*

   Fish scales serve as a natural armor that provide protection against predator attack. Their unique composition and architecture have evolved over thousands of years, and achieve an incredible degree of specific strength and toughness, complimented with high flexibility. These properties are generally mutually exclusive, even in natural materials. As such, fish scales are serving as inspiration for the design of “next-generation” synthetic armors. Recently published economic surveys forecast that the soft body armor market will exceed $600M in the next 5 years. In response to this opportunity, Blue Fin body armors has evolved from research in the material science department at University of Washington that is focused on the design and performance of fish scale structures. New flexible armors are being developed for both military and civilian markets with multi-functionality, including resistance to puncture, impact and lacerations. Based on preliminary results, Blue Fin body armors tailored for applications to gloves are achieving performance that are superior to existing products. We believe that the Blue Fin armor concepts have broad applications to additional products involving helmets, gloves and other apparel, as well as have potential to capture a substantial portion of the market share.

5. **Jonathan Onorato (Advisor: Christine Luscombe)**
   
   *Synthesis of a Mixed Ionic/Semiconducting Polymer*

   Co-authors: Modahl, Severyn; Department of Materials Science and Engineering, University of Washington
A new class of materials called mixed ionic/electronic conductors (MIECs) has the potential to be highly useful for many applications, ranging from biological sensors to battery electrodes materials. The majority of current organic MIECs are created through the blending of two materials, where one component provides ionic conductivity, and the other electronic. This leads to a complex phase behavior that is still not fully understood. However, understanding how the morphology and relative orientation of ionic and electronic conducting components effect MIEC behavior is crucial for the rational design of these polymeric systems. Here we present a new MIEC material comprising a semiconducting polymer backbone with ionically conductive side chains on each repeat unit. Specifically, the polymer was synthesized via Grignard metathesis of a poly(ethylene glycol) [PEG] functionalized thiophene ring. This specific architecture keeps the ionically conducting unit in close proximity to the semiconducting backbone, providing a novel morphology for an MIEC, and shedding light on the intricate conduction processes. Future work will target other MIEC architectures to provide additional pathways to probe the conduction and morphology interplay in MIECs. An immediate synthetic target is a block copolymer containing PEG and poly(3-hexylthiophene) [P3HT], a common semiconducting polymer. By changing the composition of this copolymer, the interface and the interactions between the PEG and P3HT can be controlled. By illuminating the involved MIEC mechanisms through this work, improvements in the design of ionic and electronic conducting systems can be systematically implemented, and potentially enable the development of novel technologies.

6. Siddharth Rath (Advisor: Mehmet Sarikaya)
De-novo Use of AI for Complexity Reduction in HPC Applications in Materials Science & Engineering by Topographical Representation of Functions
Co-authors: Rath, Siddharth; Paliwal, Swapil; GEMSEC, MSE, UW
Jorgenson, Ty; GEMSEC, MoE, UW
Starkebaum, David ; GEMSEC, MSE, UW
Overney, Rene; MoE, ChemE
Ustundag, Burak; Electrical and computer engineering, Istanbul Technical University, Turkey (visiting professor, MSE, UW)

We place topographic features of the functions, equations and molecular microstates to represent non-linear higher order differential equations and solve for the system properties with stipulated initial and boundary conditions by using deep learning algorithms that lead to directly finding asymptotically, globally optimized stable states, after several state transitions due to feedback mechanisms that would dramatically saves time and computational power. We propose a combination of pre-trained convolutional neural network (trained with topographical information of all common functions, operators and equations) as a cortex embedded into HPC or GPUs along with a problem solver AI2-10 that does not need to trace the functions repeatedly and solves the system of equations asymptotically. As a second stage development, wavelet transformed pattern features from the topographical properties of the microstate will be used instead
of differential equations in the representation of the model. In the third step, a second Deep-learning process will then be needed for solving for conformal mapping which involves complex analysis and multiple simultaneous non-linear systems of equations. When this is achieved, then direct reverse engineering of molecular system design based on AI will become possible because of the non-stochastic and sequential nature of the solution-finding algorithm.

7. Daniel Shea (Advisor: Bruce Hinds)
*Dynamic electrochemical membranes for cyclic protein transport*
Co-authors: Akkineni, Susrut; Materials Science & Engineering, University of Washington

Recently, a mesoporous anodized alumina oxide membrane has been integrated with electrochemically functionalized nanoscale electrodes for selective and continuous protein separations [1]. This electrochemically functional membrane selectively binds genetically-modified, hexahistidine-tagged proteins using chemistry borrowed from immobilized metal ion affinity chromatography and subsequently pumps the protein across the membrane with alternating, sequential voltage pulses. The electrodes are templated across the mesoporous membrane surface and approximately 20 nm into the pore entrances, providing a convenient geometry for specific target capture while blocking transmembrane transport of non-specific proteins during the binding cycle. During the release cycle, imidazole is electrophoretically pumped towards the bound protein to facilitate release of the protein. Imidazole concentration is carefully controlled to keep the top surface of the membrane pores blocked while facilitating protein release at the bottom edge of the electrode inside the membrane pores. This strategy balanced protein release efficiency to improve selectivity, resulting in a separation factor for GFP:BSA of 16:1 (mass/mass). The existing, unoptimized platform demonstrates throughput of the 0.75 cm² area membrane has comparable throughput as 1 mL of commercially available chromatography columns. Our current work reported here focuses on improving selectivity and throughput to improve platform viability by measuring the kinetics of NTA-mediated protein binding and imidazole-based protein release on the modified electrode surface.


8. Ryan Toivola (Advisor: Brian Flinn)
*Mechanochromic and Photochromic Fluorescence in Epoxy*
Co-authors: Jang, Sei-Hum, MSE, UW
Mannikko, Donald, Chemistry, UW
Stoll, Stefan, Chemistry, UW
Jen, Alex K-Y, MSE, UW
Flinn, Brian D, MSE, UW
Mechanochromism in solid polymers has great potential as the basis for the next generation of damage detection sensors. Our observations of mechanochromic fluorescence in a specific structural epoxy formulation have special implications for the aerospace industry, which uses epoxy quite often as a matrix material for carbon fiber composites. We have explored the mechanism by which this epoxy formulation displays mechanochromism using deformation in uniaxial compression coupled with time-resolved fluorescence spectroscopy (TRFS) and electron parametric resonance spectroscopy (EPR), and collected evidence that the mechanochromic fluorescence is generated by bond rupture leading to formation of stable radical species. Similar fluorescent species can also be created in the epoxy via a photochromic reaction, and studies of this reaction using Fourier transform infrared spectroscopy (FTIR) along with TRFS have suggested potential reaction mechanisms for the creation of the stable radicals involved.

9. Ryan Toivola (Advisor: Brian Flinn)
Witness Surface Coatings – Thermal Damage Detection
Co-authors: Sei-Hum Jang, Zhong’an Li, Brian Flinn, Alex Jen; Department of Materials Science and Engineering, University of Washington

Thermal damage of carbon fiber composite parts during operation and repair can significantly reduce the mechanical properties of the part, especially matrix-dominated properties like interlaminar shear strength. The detection of thermal damage requires specialized instruments that can be challenging to apply in the field. We have developed thermally activated fluorescent films and coatings that can sense thermal exposure of a surface by changing color and fluorescent emission intensity. These films and coatings may be permanent or removable, and the color and fluorescence changes are irreversible, creating a permanent record of the thermal history of the surface. We have developed films and coatings for three temperature ranges, corresponding to normal use, repair, and thermal damage-causing temperatures in epoxy-matrix composites. Potential applications of these films in the aerospace industry include structural health monitoring, lightning strike detection, cure and repair monitoring, and thermal damage detection.

10. Deniz Yucesoy (Advisor: Mehmet Sarikaya)
Biomimetic Tooth Repair: Amelogenin-Derived Peptides enable in vitro and in vivo Dental Hard Tissue Regeneration
Co-authors: Fong, Hanson; Department of Materials Science and Engineering, University of Washington
Saadat, Sanaz; Department of Oral Health Sciences, University of Washington
Dogan, Sami; Department of Restorative Dentistry, University of Washington

Caries is a global health issue that affects a large percentage of the population despite the widespread use of fluoride and other preventive treatments. Early stage carious lesions
are associated with a variety of clinical conditions, including white spot lesions, incipient caries, and hypersensitivity. If left untreated, caries can lead to tooth loss or require complex restorative procedures. The aim of this study is to develop a peptide-based biomimetic remineralization treatment to restore the demineralized dental hard tissues. For this purpose, we have identified a set of remineralization-directing peptides derived from amelogenin. This is achieved through a design algorithm which includes biocombinatorial selection using peptide libraries, similarity analysis using bioinformatics tools, molecular dynamics simulations, and iterative binding and mineralization assays. The remineralization was performed both under simulated physiological conditions in vitro and in vivo by delivering the peptide and ionic calcium and phosphate, either in aqueous solutions or in a gel formulation. Following the treatment, the structure and morphology of the remineralized tissues were characterized in detail using scanning electron microscopy and energy dispersive X-ray spectroscopy. Local mechanical properties, including elastic modulus and hardness, were determined using nanoindentation tests. In both aqueous solution-based and gel formulation-based treatment modalities, the peptide treated test groups resulted in the formation of continuous hydroxyapatite mineral layer on both enamel and dentin, at a rate of approximately 5-10 µm/hr. More significantly, cross-sectional SEM imaging revealed that the mineralized layer formed a transition region by completely integrating with the underlying dentin, similar to dentin-enamel junction (DEJ). The resulting mineral layers had mechanical properties that are comparable to that of dentin. The procedure developed here has the potential for clinical implementation in a variety of formulations as well as for developing over-the-counter products in novel dental health care.

11. Yong Cao Zhang (Advisor: Christine Luscombe)

Semi-Interpenetrating Polymer Networks for Stretchable Electronics

Recently, there has been growing interest in producing stretchable semiconductors. These materials could enable new technologies, such as body-integrated electronics, and improve performance of current wearable devices. Blending semiconducting polymers with elastomers is an approach that has the potential to achieve materials with both improved mechanical properties and mobility. Additionally, considering the conditions of the environment for use, a good chemical resistance is expected and an elastomer-based interpenetrating polymer network (IPN) system could increase the chemical resistance towards different solvents with little sacrifice of the elongation due to its crosslink properties. In this work, we explore a semi-IPN based stretchable material, which blends poly(3-hexylthiophene-2,5-diyl) (P3HT) with crosslinked polybutadiene (PB). This blend material is then spin-coated to produce films of thickness appropriate for devices, and then the PB is crosslinked under UV irradiation using 1,6-dibromohexane as the initiator. This work’s initial data demonstrates that this system increases the stretchability by at least 3 times the literature values for P3HT, while the mobility only decreases by half. AFM analysis of the semi-IPN system shows that P3HT domains form percolating networks, maintaining continuous pathways for charge transport. In order to probe these results,
we will optimize the device fabrication conditions to increase the mobility and measure
the chemical resistance in diverse situations.

12. Ting Zhao (Advisor: Alex Jen)

Fabrication of Highly Oriented MAPbBr₃ Thin Film through Ion Exchange for High Color
Purity Green Light Emission

Co-authors: Liu, Hongbin ; Chemistry, UW
            Ziffer, Mark E. ; Chemistry, UW
            Jo, Sae Byeok; MSE, UW

In this work, we developed an ion exchange methodology to further improve MAPbBr₃
thin film quality and related light-emitting diodes performance. With theoretical study
conducted to understand the ion exchange behavior between 2D and 3D perovskites, a
PEA2PbBr₄ thin film was successfully exchanged into MAPbBr₃, which preserves the
highly-ordered orientation of 2D perovskite and forms small crystallites with much
improved coverage. This ordered crystal alignment and improved morphology reduces
defect density in the film and thus non-radiative recombination, and eventually leads to
extremely narrow green electroluminescence (EL) with 13.4nm FWHM compared to
~20nm in others’ study. This improved color purity demonstrates the potential of this new
processing method in fabricating high quality organic-inorganic hybrid perovskite thin
films for efficient LEDs.

13. Peter Pauzauskie

UW Molecular Engineering Materials Center

The University of Washington Molecular Engineering Materials Center (UW MEM-C)
dresses fundamental problems in materials research that push the frontiers of science,
accelerate the development of future advanced technologies, and address challenges of
broad national and societal importance. MEM-C's research activities stress innovation in
the design, discovery, and application of complex electronic and photonic inorganic
materials with low dimensionality. MEM-C also spearheads education, training, and
outreach programs to prepare tomorrow’s leaders in science and technology, with
signature programs focusing on promotion of (re)entry of veterans into
science/technology/engineering/mathematics (STEM) career tracks, and early
recruitment/mentorship of students to STEM from underrepresented/underserved
regional high schools. Additional activities include REU/RET/REM programs, regional K-20
outreach, regional partnerships for public engagement, and interdisciplinary curriculum
development. MEM-C further strengthens ties between UW and industrial, international,
and National Laboratory partners through sponsored internships and collaborations.
MEM-C shared facilities provide lasting infrastructure that promotes the activities of the
Center as well as of the broader campus and regional materials science communities.