Research Overview

Biomaterials and Biotechnology

Catalysis and Electrocatalysis

Computational/Thermodynamics
Christopher S. Brazel – Milad Esfahani – Ian Sheehan – Tibor Szilvási – Steven Weinman – Evan K. Wujcik

Electronic Materials and Devices

Energy/Environmental/Water

Membranes and Polymers

Graduate Coordinator
Dr. Yuping Bao, ybao@eng.ua.edu
Program Highlights

Innovation, Entrepreneurship, and Creating New Opportunities

Our students and faculty are constantly exploring new ideas, venturing into new areas, and looking for solutions to society’s most pressing challenges. Translating a theoretical concept into a tangible product is one of the most exciting aspects of our research portfolio, often leading to a patent, a new business venture, or a licensing opportunity. Did you know...Prof. Huang currently holds 43 U.S. patents!

Faculty Leadership and Student Mentoring

We strive to create a challenging and supportive research environment for our students, by providing opportunities to work side-by-side with some of the most creative and intellectually-renown researchers in the world. With publications in top journals and some of the most prestigious academic awards in the world, our students and faculty work together as a team. Did you know...our faculty may have already contributed to your education with their textbooks (Fundamental Principles of Polymeric Materials, Prof. Brazel; Separation Process Essentials, Prof. Lane) or mobile applications (Chemical Engineering App Suite for iPhone/iPad, Prof. Bara)!

On-Campus Facilities and International Exposure

Our facilities have been transformed by a recent investment of $240 million to create the Science and Engineering Quad, with modern labs, environmental sustainability, and access to state-of-the-art analytical characterization tools. Our capabilities are leveraged to form international partnerships and research collaboration opportunities for our students and faculty around the globe. Did you know...our students regularly receive international research recognition, and our faculty have won some of the most prestigious international awards (Fulbright Distinguished Scholar, Prof. Brazel; Humboldt Research Prize, Prof. Gupta)!

Tuscaloosa, AL: The University of Alabama is located in the heart of Tuscaloosa (https://visittuscaloosa.com), home to one of the most beautiful campuses in the nation, along with a very mild climate and a low cost of living. It is about a 4-hour drive to the gulf coast where you will find some of the most breathtaking beaches in the world (https://www.gulfshores.com/). Birmingham is the largest neighboring city (1-hour drive), with a population of approximately 1 million residents. If you need more information about The University of Alabama and life on our campus, please visit: https://www.ua.edu/about/
Research Support

Funding the Best and Brightest Ideas

Approximately 30% of the faculty have received NSF-CAREER Awards (NSF’s most prestigious award in support of early-career faculty), as well as other national recognition of research and teaching excellence.

A Period of Unprecedented Growth

Research funding has been growing at a rapid pace, creating new opportunities and increasing the impact of our work. Over the last five years, the departmental research funding has been growing at an average pace of over 100% per year!

Broad Research Support

Research projects are sponsored by a wide variety of state, regional, and federal agencies, as well as private companies. Whether you are interested in working with a federal agency, a private company, a government laboratory, or ultimately pursue a career in academics, we can help pave the way.
Faculty Research Profiles

2021/2022
Dr. Bao’s group focuses on designing novel multifunctional nanoparticles for biomedical applications, such as targeted drug delivery, bio-imaging, and drug discovery.

Magnetic nanoparticles have significantly advanced cancer treatments through targeted drug delivery and localized therapy. Magnetic nanoparticles further make simultaneous therapy and diagnosis possible as magnetic resonant imaging (MRI) contrast agents.

One of the unique aspects of Bao’s research is the creation of a suite of iron oxide nanoparticles of different shapes as MRI contrast agents and for other biotechnology related applications. These shapes include spheres, cubes, nanowires, plates, flowers, etc.

Much of Dr. Bao’s work is directly related to the engineering of material interfaces. Her group developed a facile method to attach various molecules onto nanoparticle surfaces for water solubility and desirable functionality, such as tumor targeting.

In collaboration with UAB and Biological Science Department at UA, Bao’s group also designs nanostructures for the delivery of modulator drugs to the brain and nanostructures for drug screening from complex matrices.

Recent Publications


Dr. Bara’s research group is focused on development of advanced polymer materials, energy efficient separations, green chemical manufacture, 3-D printing, big data, and scientific apps for iPhones and iPads.

Dr. Bara is a recognized leader in the design and synthesis of advanced polymers and composites based on ionic liquids. These materials provide unprecedented opportunities to create stable nanostructured materials with highly tunable chemical and physical properties for applications including gas separation membranes, water purification, superabsorbers, shape-memory and self-healing, and 3-D printing.

Dr. Bara’s group is also very active in the synthesis and study of new “green” solvents and their roles in polymer upcycling and depolymerization. Dr. Bara has also developed several widely used apps for iPhones/iPads including Chemical Engineering AppSuite.

Recent Publications


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The Brazel Laboratory is interested in developing and understanding the chemical and biological properties of materials for medical, biopharmaceutical, and chemical processing applications. Recent foci in the lab include: (1) developing a robust toxicity assay to evaluate polymer films for single-use cell culture/fermentation as well as ionic liquids used in recycling of materials, and (2) development of targeted magnetic micelles that combine hyperthermia with drug release for cancer therapy.

We seek to understand the fundamental chemistry and physics of the materials and phenomena to guide the optimization of materials used in bio- and chemical-processing and drug delivery devices, while considering the interaction of new materials with both the human body (therapeutic effect) and the environment (potential toxicity).

In the area of toxicity, the biopharmaceutical industry is growing ever-more dependent on single-use plastics for sterile, off-the-shelf solutions to growing cells. With this comes the potential exposure of cells used to manufacture complex medicines to plastics additives that may impair cell growth or lead to unsafe by-products. By developing toxicological assays, standardized tests can be developed to compare products made across the industry and safer plastics developed to ensure high quality production.

In the area targeted magnetic micelles, the combination of nanoparticles with polymeric micelles allows a magnetic field to trigger release of chemotherapy agents. Our lab includes synthesis of iron oxide nanoparticles, self-assembly of poly(caprolactone-b-ethylene glycol) block copolymers and characterization of the properties and functionality of these materials. Electron microscopy (TEM image of magnetic micelles below, left), and high frequency magnetic heating (envisioned using an infrared camera, bottom right) are used to validate the system.
Milad Rabbani Esfahani

Functionalized Membranes For Sustainable Water and Energy Production, Water Purification and Desalination, Nanomaterials Environmental Safety

Dr. Esfahani’s group uses a multidisciplinary approach to develop novel functionalized membranes with ultimate goal of water-wastewater treatment and energy production.

Our research field is at the interface of several disciplines including separation science, nanotechnology, materials science and colloid science that links to the water-energy-food nexus. In the field of functionalized membranes, we are developing catalytic membranes with self-cleaning properties where they can provide higher permeability and less fouling. Our research group will develop different strategies to incorporate nanoparticles with specific properties such as photo catalytic activity of titanium dioxide nanoparticles, highly adsorptive properties of multwall carbon nanotube, anti-bacterial properties of silver nanoparticles, and high absorptive properties of gold nanoparticles to the polymeric structure of the membranes for creation of advanced self-cleaning membranes. We use both computational and experimental approaches to design engineered membranes for water desalination, water purification and energy production. Also, in the field of nanomaterials environmental safety, we are studying the transport and fate of nanomaterials in aquatic environment.

Recent Publications


Dr. Gupta’s group focuses on controlled synthesis and assembly of nanomaterials and nanostructures, with emphasis on the exploration and manipulation of materials’ physical and chemical properties and their potential applications.

Spintronics, also known as magneto-electronics, is an emerging technology which exploits the intrinsic spin of electrons and its associated magnetic moment, in addition to its fundamental electronic charge, in solid-state devices. Spintronics exploits electron spin, creating a new class of devices that can potentially be scaled down to nano-dimensions and can also provide additional functionality. The group is interested in the growth and characterization of novel magnetic thin films by a variety of deposition techniques, including chemical vapor deposition, pulsed laser deposition, etc. for the fabrication of devices, such as magnetic tunnel junctions and spin-based semiconductors, and their application for storage, memory, and logic-based devices.

Nanomaterials are of great interest for a wide range of applications, including catalysis, data storage, biotechnology/biomedicine, etc. In particular, the synthesis of monodisperse uniform-sized nanocrystals using solution-based methods is of key importance for these applications because of their strong dimension-dependent physical and chemical properties. Dr. Gupta’s research group is interested in the synthesis of functional oxides and chalcogenides in the form of nanoparticles and other nanostructures with controlled shape, size, structure, etc.

In addition to traditional methods for the synthesis of inorganic nanomaterials, novel approaches are being developed that exploit advances in biotechnology. The bio-inspired approach to materials synthesis has successfully utilized cells, viruses, and biomolecules, such as nucleic acids, proteins, etc., to produce inorganic nanomaterials with controlled crystal morphology, phase structure, and size, under mild conditions.
Dr. Harris’s group studies chemical reactions occurring at solid surfaces in order to develop environmentally friendly catalytic routes to fuels and chemicals.

Catalysts provide energetically feasible pathways for chemical reactions to occur. The Harris group works to understand these materials as they exist during reaction in order to develop processes to upgrade abundant feedstocks to desirable chemicals. We synthesize catalysts, including supported metal nanoparticles and crystalline microporous solids, and characterize their physical and chemical characteristics at the molecular level. These materials are used for studies of the kinetics and mechanisms of chemical reactions, with aid from in situ spectroscopic tools, to develop improved processes that reduce the environmental impacts of the production of fuels and chemicals.

Research in our group includes efforts to transform shale gas to useful chemicals. Abundant reserves of shale gas in the United States have provided a surplus of light alkanes and provided an opportunity to develop new catalytic processes to transform these feedstocks into useful chemicals and fuels instead of flaring these gases at geographically isolated shale gas wells. Emerging classes of catalysts have demonstrated exciting prospects for the selective transformation of these light alkanes into liquid chemicals that are more easily transported.

A second area of research involves upgrading of oxygenates derived from biomass. These highly-functionalized molecules can act as platform molecules for production of fuels, polymer precursors, solvents, flavorings, perfumes, and pharmaceutical precursors. Production of these high-value chemicals currently requires non-renewable feedstocks and often generates toxic by-products, leading to opportunities to explore selective catalytic transformations that alleviate existing environmental impacts while producing renewable specialty chemicals.
Qiang Huang
Associate Professor
Ph.D. Chemical Engineering
Louisiana State University, 2004

Electrochemical Engineering for Nanomaterials, Nanostructures and Nanodevices

Dr. Huang’s group focuses on developing electrochemical technologies to fabricate new materials and structures for applications in microelectronics, renewable energy, and quantum devices.

Electrochemical reactions are chemical reactions that involve electron transfer. Dr. Huang’s current research focuses on such reactions in conjunction with materials sciences, investigating the impacts of the chemistry and process on the material structure and properties. Two example applications are for microelectronic and quantum devices.

The convenience of our daily life and the development of modern technology heavily rely on the advancement of microelectronic and semiconductor devices. Interconnect is a nanometer sized network of metal wires in integrated circuits, enabling the communication between each semiconductor devices (transistors). We are exploring the electrochemistry and electrodeposition process for the fabrication of new interconnects, which are much needed to enable the further advancement of integrated circuits, as well as our computers and cell phones. (Figure on the left)

Quantum computing is believed to represent a completely new paradigm, where the data are no longer zeros and ones but rather can be any values in between. We are developing new electrochemical methods to make superconducting films and superconductor-based quantum junction devices. Such films allow the passage of electrons without any resistance, avoiding electrical heating and temperature perturbation on the cryogenic quantum computer. (Figure on the right)


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The Kim laboratory is working on bioprocessing expansion of cancer stem cells to better assist translational medicine. Cancer stem cells (CSCs) are considered the stem cell-like pluripotent cancer cells that cause relapse in patients even after the most rigorous treatment.

Pharmaceutical companies, however, typically use several decades-old cancer cell lines during their drug development because, among many reasons, (1) CSCs are hard to acquire and (2) are limited in number. It is becoming increasingly recognized, however, drug development must be based on CSCs to develop better drugs that target the "real culprit" in tumors. Therefore, the work at the Kim Laboratory aims to bridge the oncologists with the engineers by developing large scale quantities of CSCs using engineering principles and systems biology tools (e.g. proteomics) for the mass production of CSCs from primary patient tissues and cell culture. By doing so, they hope to assist in the drug development by providing a more relevant and closer-to-clinic resource of cancer cells.

Recent Publications


As electronic, magnetic and photonic devices become more sophisticated, there is an ever-pressing need to fully understand the physics and chemistry of solid interfaces. Technologies such as spin valves, field effect transistors, and nanolaminate optical coatings are all comprised of ultra-thin films in the nanometer thickness regime.

At this dimension, bulk thermodynamic properties governing film stability, diffusion, and reactions as well as bulk electron transport mechanisms that determine device performance no longer apply. Hence, there is a need to develop novel preparation procedures for thin film structures with abrupt interfaces for incorporation in new devices and in test devices which probe fundamental physical phenomena like electron scattering at interfaces in giant magneto resistance (GMR) and tunneling magneto resistance (TMR) recording heads.

Atomic Layer Chemical Vapor Deposition is a promising technique for the fabrication of nanometer scale thin films for alternate high k gate dielectrics in field effect transistors, dielectrics for magnetic tunnel junctions, and metal thin films for spin valves, optical coatings, or diffusion barriers for interconnects. The process involves a separation of the reaction sequence into two self-limiting steps dependent on the availability of functional groups present on the surface. This allows the formation of an atomic layer one step at a time, resulting in excellent film uniformity, conformality and thickness control.

Attenuated total reflectance Fourier transform infra-red spectroscopy (ATR-FTIR) reaction cell is used to observe initial reaction pathways in real time. An IR light beam is focused on the backside of a heated Si, Ge or ZnSe ATR crystal and is bounced though as it is totally reflected at the gas surface interfaces. Some of the light extends as an evanescent wave into the reaction zone on the topside of the ATR crystal and is used to identify key chemical groups involved in the reaction sequence.
Dr. Koh’s group focuses on engineering multifunctional materials through the intentional design of interfaces. Current research focuses on materials for soft robotics, stretchable electronics, sensing, and environmental remediation.

As devices become more advanced in the fields of defense, health, and manufacturing, it is no longer enough for materials to have a single function or a be useful to only a single application. Materials that are responsive and multifunctional are key to creating robust, practical, and adaptive systems. The Koh lab seeks to develop these materials through the engineering of internal and composite interfaces either through the manipulation of existing chemistry or the addition of novel components.

Much of the current work in Dr. Koh’s lab focuses on developing soft materials which are both deformable and have electronic, magnetic, or sensing capabilities. Applications of these materials include stretchable electronics (ex. wearables and health monitoring), soft robotics (ex. human-machine interfaces and manned-unmanned teaming), and environmental contaminant sensing (ex. heavy metals and petroleum derivatives).
Dr. Peng’s group focuses on understanding and applying vapor-substrate reactions to synthesize novel materials and to control the material interfaces (down to the atomic level) in order to improve the performance of materials and devices in microelectronics, solar energy conversion, separations.

We investigate the nucleation and growth materials by in-situ/ex-situ analytic methods in order to understand surface/interfacial chemistry and micro-structures of materials, and establishing the structure-property relationship of materials. Dr. Peng works on the following projects:

Recent Publications


The Rao Laboratory is developing engineering tools to unravel the mechanisms associated with the role of microenvironment in cancer progression, therapeutic response and resistance.

The oncogenic progression of cancer from the primary to the metastatic setting is the critical event that defines stage IV disease, no longer considered curable. Despite some success in developing a suite of therapies, a key challenge that continues to hamper cancer treatment is the frequent development of drug resistance, particularly in the metastatic setting, resulting in disease relapse and often mortality. Most existing experimental models to investigate tumor cell responses to therapeutic treatments and examine mechanisms of drug resistance utilize two dimensional (2D) substrates (e.g., plastic, glass) that largely fail to recapitulate the complex in vivo environment.

Our research group is designing three dimensional (3D) biomaterial scaffolds (e.g., hydrogel scaffolds, and porous scaffolds) as tools to mimic features of tissues that could serve as platforms for elucidating physiologically relevant cellular behaviors, drug screening and discovery, as well as mechanisms of drug resistance in the context of cancer therapeutics in vitro and in vivo. In addition, we are developing biomaterial tools that could be employed for sensing and modulation of drug resistance. We are also applying systems biology approaches to understand the underlying mechanisms of therapeutic resistance in physiologically relevant 3D microenvironments. This knowledge could be subsequently utilized to devise strategies that can reprogram the microenvironment to halt disease progression. Given that drug resistance is a major issue noted across multiple types of cancers, this work would have far reaching implications in drug discovery and development, thereby transforming current treatment strategies.
Dr. Ritchie’s laboratory focuses on the addition of active properties to passive materials. This work has resulted in adsorptive membranes for antibody purification, highly charged membranes for protein separation and concentration, membrane catalysts, and anti-microbial surfaces. Commercial production of functionalized membranes and scale-up are also of interest.

The group’s interest in adsorptive membranes has been focused on antibody purification. The work is continuing and evolving to include other biomolecules and more complex adsorption sites. Adsorptive membranes are fully synthetic and high capacity, and are capable of achieving similar selectivity to affinity resins.

We also have a strong interest in commercial production techniques and applications for functionalized membranes. Currently, work is focused on high volume systems containing proteins and other biomolecules. The goal is to concentrate proteins similar to conventional microfiltration and ultrafiltration processes, but at much higher flux through a combination of separation mechanisms beyond size exclusion.

The group’s interest in acid catalysis has been on low temperature reactions where the competing solid-phase catalyst is strong acid ion exchange resin. Our current interest is adapting membranes for long-term operation in industrial systems. We are targeting applications with reactive distillation is currently employed.

We have also been active in synthesis of anti-microbial materials for application to dairy systems. Components of spiral-wound membrane elements can be modified to include anti-microbial surfaces. The particular application of interest is for Listeria Monocytogenes reduction in milk processing.

We have a new area of research on particle separation using non-woven materials formed from recycled plastics. Our focus will be on synthesis of fibers used in the application, as well as construction of composite materials that can provide similar performance to commercial filters applied to indoor air filtration.
Dr. Sheehan’s group uses experimental and modeling approaches for evaluating reaction kinetics and phase behavior of mixtures in supercritical fluids. Their research develops sustainable processes for synthesizing commodity and fine chemicals.

Supercritical fluids (SCFs) are compressible fluids consisting of chemical species under temperatures and pressures exceeding their critical point. The properties of SCFs (e.g., density, viscosity, diffusivity, etc.) are intermediate of those of gases and liquids, and their compressibility facilitates “tuning” of their properties by adjusting temperature and/or pressure. As such, the tunable properties of SCFs allows for enhanced control over phase behavior and solubility of chemical species in SCFs, which in turn, has implications for the design of reaction and separation processes.

The Sheehan group investigates the phase behavior and solubility of chemical species in SCFs and evaluates the chemical kinetics of associated reactions of interest. They evaluate SCF systems via in situ spectroscopic and ex situ analytical methods and leverage computational modeling tools for quantifying chemical kinetics and optimizing process conditions. The overarching research objective of the Sheehan group is to develop novel and sustainable chemical processes that mitigate the use of toxic chemicals and promote process intensification by integrating reaction and separation unit operations.

Recent Publications


The Summers lab is working to metabolically engineer bacteria and yeast cells to produce chemicals, fuels, and pharmaceuticals. Specifically, the group focuses on engineering enzymes, gene networks, and genetic regulatory elements in microbial cells.

Caffeine is a natural product produced by many plants and consumed by humans worldwide. However, high caffeine consumption has also led to large amounts of caffeinated waste from coffee and tea processing plants. This can have detrimental environmental effects, as caffeine is toxic to most bacteria and insects. The Summers lab has a growing collection of bacteria capable of growing on caffeine as sole carbon and nitrogen source. From these bacteria, new genes and enzymes are being discovered that can be used in a variety of biotechnological applications. Through a combination of systems biology, protein engineering, and molecular biology, the lab is engineering yeast to simultaneously decaffeinate coffee waste and ferment the sugars in the waste to ethanol. Additionally, bacterial strains to produce high-value chemicals from caffeine are being created. The group is also working to determine the structures of caffeine-degrading enzymes in bacteria using X-ray crystallography.

Other projects in the Summers lab include metabolic engineering of probiotic bacteria for in situ delivery of amino acids, characterization of genetic regulatory elements in probiotic bacteria, design of modular plasmids for metabolic engineering of E. coli, Saccharomyces cerevisiae, and other microbial strains, and construction of novel riboswitches that recognize small molecules.

As society moves away from use of petroleum resources for production of fuels and chemicals, their replacements must come from natural, renewable resources. To meet this need, the Summers lab seeks to engineer bacteria and yeast cells to produce bulk and fine chemicals from biomass. In addition to these chemicals, the group is looking at production of pharmaceuticals and nutraceuticals in metabolically engineered microbial cells.
Dr. Szilvási’s research group focuses on designing functional materials with well-tailored specific properties by applying computational methods.

Societal needs require to develop efficient and cheap functional materials for various technologies. Our group is committed to accelerate the development of new materials by using fast and accurate computational methods to screen potential candidates and pinpoint materials with desired properties. Using computational methods, we can potentially save millions of dollars and years of tedious experimental efforts and therefore can provide solution for pressing problems in time.

Dr. Szilvási’s research group aims to focus on engineering interfaces and molecular materials. Specifically, the group intends (i) to optimize catalysts relevant for industrial processes, (ii) to identify functional materials for soft matter applications, (iii) to design complex interfaces for energy and sensor applications. To achieve these goals, Dr. Szilvási’s research group also develops computational methods and protocols that can provide more accurate predictions for material design.
Dr. Turner’s group uses computer simulations to investigate adsorption and reactions on surfaces and at interfaces. Their work helps guide the synthesis of new nanomaterials, identify new catalysts for environmental applications, and design unique solvent molecules for CO₂ separation technologies.

The Turner group uses molecular simulations and quantum mechanical calculations to screen new materials for a variety of clean energy technologies. In the field of catalysis, we are using kinetic Monte Carlo simulations to help identify an environmentally-benign route for synthesizing propylene oxide using gold-based nanoparticles. Also, we are using molecular simulation tools to screen solvents for producing thermoelectric materials (such as Bi₂Te₃), which can be used to capture waste heat from a variety of sources. In terms of CO₂ capture, we are developing efficient simulation tools for quickly screening and identifying effective solvents and polymers for CO₂ capture applications. In all projects, we work closely with experimental collaborators, in order to regularly benchmark our models and develop reliable predictions.

Recent Publications


http://TurnerResearchGroup.ua.edu ◦ (205) 348-1733
Dr. Weinman’s group focuses on functionalizing and synthesizing membranes to improve current water treatment membrane technologies.

Membranes are semi-permeable barriers that separate substances when a driving force is applied across the membrane. The Weinman group works to provide solutions to current environmental and wastewater challenges by developing new membrane technologies.

The Weinman Group focuses on synthesizing and studying the fundamental properties of thin-film composite membranes for nanofiltration and reverse osmosis applications. This will allow us to better understand what factor(s) influence membrane properties and utilize this understanding to enable new separations.

Progressive decline in water permeability due to fouling is one of the largest costs associated with membrane processes in water treatment. My research focuses on surface modifying membranes to reduce various types of fouling (oil, biological, scaling, etc.).

Another project area involves creating membrane adsorbers and solvents to capture compounds of interest. There is a need to selectively remove persistent pollutants and high value products from water and wastewater streams.

Lastly, the Weinman Group is exploring new solvents for brine remediation where membranes cannot be used.
The Materials Engineering And Nanosensor (MEAN) Laboratory investigates and develops advanced materials, fundamental biomedical & environmental sensor platforms, and wearable electronics.

The MEAN Laboratory lies at the interface of materials science/engineering, polymer science, nanotechnology, and surface (sensor)/interfacial science. From studying fundamental material properties and applications of nanomaterials comes innovative nanosensors, biosensors, wearable sensors, and bio-compatible materials applicable to a number of fields and disciplines.

Recent Publications


The Zhao Lab develops novel polymeric biomaterials for various biomedical applications, with emphasis on drug delivery and tissue engineering. The projects are driven by developing new technologies for the treatment of specific diseases.

Tetrodotoxin (TTX) is a potent neurotoxin that blocks voltage-gated sodium channels on the cell surface. TTX is 3000 times more potent analgesic than morphine without the opioid-like side effects. However, the principal reason that TTX has not achieved clinical use despite their great potency is concern over their associated systemic toxicity. TTX toxicity causes neural blockade and muscular weakness resulting in diaphragmatic paralysis leading to respiratory arrest and death. The severe systemic toxicity limits the dosing of TTX, and therefore limits the maximal duration of analgesic effects achievable.

The primary objective of Zhao’s research is to use materials-based approaches to address the limitations imposed by the toxicity of TTX, and to move toward clinical translation of TTX for the pain treatment.

Other projects in Zhao lab include the development of polymeric vectors for gene therapy, and biomimetic scaffolds to enhance delivery of stem cells for tissue regeneration.