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Material Collaboration

Materials science touches almost every aspect of modern daily life, from amazing advances in communication (computers, smart phones, televisions, etc.) to composite materials (aerospace and automotive improvements) to medical (compatibility of artificial implants) and more. Advances in the field are expected to be key toward efficient energy storage and offers promise for alternative drug delivery, including for cancer treatment.

Although it is a relatively new field from an academic perspective, materials science offers abundant external funding for research, a high demand for graduates and targets fundamental and applied outcomes. A focus in this area also places the University, as stated in *Illuminate*, "distinctly at intersections of technology and Christian stewardship of God's earth and its resources."

Baylor Magazine presents brief descriptions for a few of the more than a dozen Baylor faculty with active materials science projects that have garnered external funding, provided learning experiences for undergraduate and graduate students, and identified solutions to challenges facing high-visibility industries.

Mechanical Engineering

Analyzing and designing lightweight, durable composites

Formed by combining plastics with varying types of fibers for strength, composites are used to create sturdy, lightweight materials for a wide range of applications, including cars and airplanes.

"With recent advances in the fabrication of materials, it is becoming increasingly important for the design engineer to have accurate and effective tools to aid them in the creation of advanced, multifunctional products," Dr. David Jack, associate professor of mechanical engineering, says. "My work spans the size spectrum, from the nano to macro, and covers industrial applications ranging from niche military aerospace multifunctional aircraft panels to large-volume, low-price automotive components."

One of his current projects partners with L3 Aerospace Systems Waco, which works on a range of aircraft. Over the course of several years, Jack has created technology that uses sound to create images of materials made with layered composites, enabling those who are creating or analyzing them to see what is happening inside.

"It's the same idea as going to the hospital and getting an ultrasound," Jack says. "We can see within each layer of the composite. In the past, companies would overdesign a product, such as a wing for an airplane. Our process eliminates a lot of testing done during the production process, which improves quality and reduces overall expenses."

He credits his interest in the analysis and design of lightweight, durable composites to his mentor, Dr. Doug Smith, having studied with Smith at the Colorado School of Mines and the University of Missouri. Both scientists have now found a home teaching and conducting research at Baylor as faculty members in the School of Engineering and Computer Science.

Jack works with a team of colleagues in the Baylor Research and Innovation Collaborative (BRIC) to conduct his research and to contribute to the work of fellow mechanical engineering faculty members, including Dr. Alex Yokochi, Dr. Bill Jordan and Dr. Sunghwan Lee.

Physics

Controlling the material properties of light

Faculty in the Department of Physics, within Baylor's College of Arts and Sciences, are focused on creating what might be thought of as a "tiny revolution"—using nanotechnology to control the material properties of light.

Through the development of an ultrathin film known as a metasurface, they are creating a material that can absorb 100 percent of light hitting its surface and then, through applying a finely tuned electrical voltage to the material, filter out specified colors and even guide beams of light.

“This work could potentially revolutionize nanoscale chemical imaging techniques,” Dr. Zhenrong Zhang, associate professor of physics, says. “It could make a technically challenging tool accessible to various fields, including medical imaging, the semiconductor industry, and ultrathin optics.”

Fellow Baylor physicists are among her collaborators, including Dr. Ken Park, Dr. Howard Lee and Dr. Marlan Scully, Distinguished Research Academician of Science and Engineering. Zhang’s research group also provides opportunities for post-doctoral researchers, graduate students and undergraduates to gain valuable, hands-on experience, furthering their education and opening doors to a variety of careers.

“The research we are doing could improve our daily lives in the future by creating technology such as ultrathin smartphone and virtual-reality glass, as well as advanced communication systems,” Lee, one of the principal collaborators, says.

Zhang received a five-year, $500,000 National Science Foundation award to support the research on these promising metasurfaces, whose near weightlessness and absorptive capacity could significantly improve the efficiency of photovoltaic solar cells and other light-absorbing devices.

Electrical & Computer Engineering

Exploring two-dimensional materials

“Our research on graphene and other two-dimensional materials will directly benefit the nanotechnology industries,” says Dr. Jonathan Hu, associate professor of electrical and computer engineering in Baylor’s School of Engineering and Computer Science.

He says the unusual characteristics of two-dimensional materials, which consist of a single layer of atoms, allow them to have applications in areas ranging from photovoltaics and semiconductors to electrodes and water purification.

Graphene is a semi-metal composed of a two-dimensional, honeycomb arrangement of carbon atoms. Hu says graphene has drawn intense interest since its discovery in 2004 because of its unique electrical, optical, mechanical, chemical and biocompatible properties.

“The development of two-dimensional materials enables on-chip integration of electronic and photonic circuits, which would increase the speed of computation with reduced power consumption and provide new applications such as quantum information processing,” he says.

Hu notes that graduate and undergraduate students who participate in his lab’s research gain excellent training and experience that prepares them for future employment or advanced degrees. Beyond his collaborations with colleagues at Baylor, Hu also works with scientists at the University of Houston, Rice University, and the U.S. Naval Research Laboratory.

Chemistry & Biochemistry

Enhancing light capture and conversion efficiency

As an associate professor of chemistry in the Department of Chemistry and Biochemistry, located within Baylor’s College of Arts and Sciences, Dr. Kevin Shuford oversees several areas of active research. One is exploring new materials and designs to enhance light capture and conversion efficiency in solar applications as well as boosting energy and power densities in electrical energy storage devices.

“Our fundamental research is helping to lay the groundwork for new technologies that will ultimately benefit consumers by improving their quality of life,” Shuford says, explaining how his group is investigating the properties of unique nano-architectures for use in photovoltaic devices. “We want to understand the processes occurring at the electrode/electrolyte interface on a molecular level to achieve higher energy and power densities in these devices. Solar energy is an attractive alternative to combustion fuels. However, photovoltaic devices are still plagued by high prices and low efficiencies.”

Shuford and his collaborators, which include graduate and undergraduate students, make extensive use of computers in their work.

“Being a computational materials chemist allows me to study problems in fine detail on a computer to determine material properties and ascertain how these properties respond to chemical/physical stimuli,” he says, noting that computational modeling gives him the freedom to try out new material combinations or configurations that may be currently inaccessible to experimentalists for various logistical reasons.

“There are an effectively infinite number of ways to assemble elements in the periodic table together into materials,” Shuford says. “We are just scratching the surface on what may be possible with computational materials design. This research area is poised to make major contributions to some of the most pressing issues facing society today like energy and the environment.”