Turning Innovative Science and Engineering into Values

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Message from the Department Chair

Greetings, Alumni and Friends and welcome to the fourth newsletter. After three years as the department chair, I am delighted to report that the department is in excellent shape. The department has witnessed a significant growth in enrollment at both the undergraduate and graduate levels, which is an indication of our student’s strong belief in the high quality of education that we provide. Looking at this aspect from a different point of view, our students are being hired by institutions of repute and they continue to make an impact in the outside world. This is the proudest achievement.

Graduate students continue to be well-funded. Several research projects secured from federal, state, private and international institutions are being executed. These include National Science Foundation, National Institutes of Health, Department of Defense, University of Texas System, National Natural Science Foundation of China, ArcelorMittal, CBMM-North America, and National Research Council of Science and Technology, South Korea, to list a few.

We are committed to turning innovative science and engineering into solutions that bring value to society. We try to meet the unmet needs of society, while advancing new structural and functional materials area and leveraging new research technologies.

Your support is vital to providing students with what they rely on to realize their individual potential. Your participation is truly meaningful. You know first-hand that the department is committed to educational excellence and is a hub of innovation. Its impact on metallurgical needs of the country has been huge. Every gift makes a difference. Thank you for helping to provide the students with access to UTEP’s world-class academics, teaching, and research. We sincerely hope you would agree that the department is as important now as ever (and well worth supporting), especially given the current climate. We hope that you will visit us soon to see the new face and new altitude of the department. Moreover, with your help the department can continue to go from strength to strength. Thank you for consideration.

As I mentioned at the beginning of the message, our faculty and students are enjoying outstanding success. For example, one of our students received the Materials Advantage award for outreach activities. In this Newsletter, you will read about the major strides our students and faculty are making in research and partnerships. The innovative process of ‘phase-reversion’ to obtain nanostructured or ultrafine-grained stainless steels was partially modified to manufacture endoscopic instrument. Similarly, our biomedical engineers are advancing and exploring the benefits of 3D printing for medical implants and devices.

You will also note from the examples and stories in this newsletter that the engineers have the extraordinary talent to make a difference in the world. Every moment of our time everything we do is for the welfare and well being of society. I salute the hard work of faculty and staff for not only helping the students in providing the best possible education, but for their exemplary work in taking the department to new heights and help build on distinction.

In summary, the department continues to enjoy a strong foundation. Its numerous achievements continue to motivate students and faculty to develop their knowledge and skills with great enthusiasm. These accomplishments and strengths also provide a platform for our dedicated and diverse community of students and faculty to advance in many ways: through innovation and creativity; by nurturing friendship and partnership with community, alumni, and industry; and by reinforcing the internal structures that sustain us.

On behalf of MMBME family, it is my pleasure to recognize and thank the growing community of alumni and friends, for their generous gifts and donations that helps ensure the future of the department.

Hope you enjoy this issue and please drop a line with your thoughts and comments.

Department Chair and Graduate Program Director for Materials Science and Engineering
Professor Devesh Misra

Undergraduate Program Director for Metallurgical and Materials Engineering Program
Professor Steve Stafford

Program Director for Biomedical Engineering
Professor Thomas Boland

Undergraduate Advisor for Biomedical Engineering (Minor) – Professor Binata Joddar

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Student News

ASM Award
Ramon Benitez’s outreach proposal was selected as one of the grant recipients of the ASM Materials Education Foundation Student Chapter.

Undergraduate Students Spend a Semester in South Korea

Edgar Reyes visiting a temple in Ulsan, South Korea

Ivan Montes, an undergraduate student, was always anxious to know as to what aspects of a material govern their properties and performance. This interest inspired him to pursue a degree in Metallurgical and Materials Engineering. A strong believer in a well-rounded education, Ivan developed a special interest in biomaterials. He started at UTEP in 2016 and thought about integrating materials engineering with biomedical sciences. This motivated him to start conducting research in the Biomaterials Laboratory of the department.

Alongside his mentor, Dr. Krishna Nune, Ivan is working to understand the effect of different implant materials on cellular processes. "Understanding osteoblast cell response to different metallic interfaces is crucial in the medical implant and prosthetic industry ", explains Ivan. "What we are doing here is, determining the most efficient alloy surface for the application in question" through the analysis of a series of quantitative and qualitative experiments involving biocompatibility, osteointegration, surface properties (topography, energy, and wettability), cell-material interactions, intercellular communication, and mechanical properties of the implant material.

Ivan plans to continue his research until he graduates in a few years, and then commence his graduate studies at UTEP. Meanwhile, he hopes to discover more about the vast field of materials engineering and unveil its many applications to engineering solutions in the biomedical field.

An Insight into an Undergraduate Student’s Research Perspective

In keeping with the tradition of more than 25 years, the department recognized the outstanding contributions of undergraduate and graduate students at the annual banquet held on May 5, 2017 for excellence in professional activities. The annual banquet captures the spirit of excellence that we aspire to deliver each year. It also symbolizes something much bigger. It embodies the spirit of enthusiasm of our students and faculty.

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With the inauguration of SFB, the department has five active student chapters, Materials Research Society (MRS), Materials Advantage, ASM International, American Foundry Society (AFS), Society for Biomaterials (SFB) and Biomedical Engineering Society (BMES).

**Global Experience and Academic Exchange**

The international collaboration and exchange is envisioned by the department as a high valued mechanism for promoting scientific discovery and maximizing the impact of academic and research excellence. In recent years, the faculty has collaborated with colleagues from Finland, UK, Germany, China, India, Brazil, and South Korea and is continuing. A conceptual benefit is that the students and faculty acquire greater awareness of the expertise that exists at the two ends, broadening our insights and enlarging our views. This culminates in the development of international networks for joint initiatives and information exchange, and professional development.

**Cooperative Agreement with Seokyeong University (SKU), South Korea**

The study abroad program – dual degree program with Seokyeong University continues to be a great success supported by $2 million grant from the SKU. The cooperative program includes study abroad opportunities for the students at UTEP and Seokyeong University. Participating students acquire international experience by studying in an overseas university that have Printing Nanoeengineering (PNE) courses at their university.

**Guikuan Yue Develops Cooperative Partnership with Freeport-McMoRan**

Guikuan Yue, Assistant Professor has joined hands with our friends in Freeport-McMoRan to establish state-of-the-art ‘Electrochemistry and Extractive Metallurgy Laboratory’ in the department. The focus is on research in the field of copper hydrometallurgy and electrometallurgy, electrochemistry for materials preparation and processing in aqueous or non-aqueous electrolyte, solution chemistry and thermodynamics in environmental and water treatment in mining and metallurgy industry, and corrosion. Considering his expertise, the ultimate goal for these areas involves improving the existing technology or develop novel environmentally benign or energy-saving processes, so as to address the problems in the fields of metallurgy, energy and environment.

Guikuan Yue holds a Ph.D. in Materials Engineering (hydrometallurgy) from The University of British Columbia, Vancouver, Canada. He joined UTEP in Sep. 2016 and has been continuously making efforts to interact and work with the partners in non-ferrous metallurgy industry (especially Cu, Au, Mo) in North America and Latin America to spur entrepreneurial activity in the metals sector based on technology developed by the department faculty and students. The primary objective is to contribute to the economic development of the local El Paso region, and adjacent national and international

In Spring 2017 semester, a few motivated students and Binata Joddar (faculty advisor) got together and initiated the UTEP student chapter of Society for Biomaterials (SFB) with the following vision:

- Promote biomaterials related knowledge, education and awareness at UTEP and in the El Paso Del Norte region.
- Strengthen STEM talent in biomaterials in an interdisciplinary manner.
- Raise funds to support senior design projects in the department in the field of biomaterials.
- Engage in outreach activities by visiting local high schools and demonstrating the benefits of 3D bio printing.

**Inauguration of Society for Biomaterials UTEP Chapter**

In recent years, the department has been continuously making efforts to interact and work with the partners in non-ferrous metallurgy industry (especially Cu, Au, Mo) in North America and Latin America to spur entrepreneurial activity in the metals sector based on technology developed by the department faculty and students. The primary objective is to contribute to the economic development of the local El Paso region, and adjacent national and international

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regions such as New Mexico, Arizona, Nevada, and provide training to students for future career opportunity.

Guikuan Yue is strongly engaged with Freeport-McMoRan Inc. (FMI), one of the world's leading producers of copper concentrate, cathode and continuously cast copper rod. FMI is a premier U.S.-based natural resources company with headquarters in Phoenix, Arizona. FMI is the world's largest publicly traded copper producer, the world's largest producer of molybdenum, and a significant gold producer. FMI's portfolio of metal assets includes the Grasberg minerals district in Indonesia, one of the world's largest copper and gold deposits; significant mining operations in the Americas, including the large-scale Morenci minerals district in North America and the Cerro Verde operation in South America.

In November 2016, Guikuan Yue organized a one-day field trip with senior undergraduate students to Freeport-McMoRan El Paso facility. Through the visit to Refinery and Rod Mill, students learned the industrial operation in detail to obtain a deeper understanding of what they have learned in class. Guikuan Yue is continuously interacting with FMI, in particular, with alumni, Brad Wesstrom, to understand the current issues and address them at UTEP.

Guikuan Yue visited the TC Sanchez Facility and Central Analytical Service Center in Safford, TC Tucson Facility in Arizona. He visited and discussed the mutual research interests and goals with senior management (including several UTEP alumni) for future collaboration on different aspects of copper research including heap leaching, pressure leaching, electrowinning and electrorefining, environmental, etc.

Freeport-McMoRan is very pleased with Guikuan Yue's effort and is planning to donate a number of major equipments to help establish the Electrochemistry and Extractive Metallurgy lab at UTEP, as well as share some major research facilities (e.g. mineralogy characterization) in their technology centers, to enhance copper research and training of students.

Guikuan Yue and senior undergraduates visiting Freeport-McMoRan El Paso facility. Right: Guikuan Yue visiting the TC Sanchez Facility in Safford (Arizona), and Gabe Bowman, Chief Engineer, is introducing the copper column leach facility.

Printing Nano Engineering Lab Explores Partnership with Carnegie Mellon University

The Printing Nano Engineering (PNE) lab of the department directed by Namsoo Peter Kim, Associate Professor, is exploring the creation of a partnership with Carnegie Mellon University, specifically, The NextManufacturing Center. The NextManufacturing Center is one of the world's leading research centers for additive manufacturing (AM), commonly known as 3-D printing. The center leverages knowledge from across disciplines to develop a dual graduate program, combining design optimization, materials selection and characterization, process parameter mapping, software development, final part inspection, and qualification.

An exchange of students during the summer of 2017 was the first step in this project of cooperation between UTEP and CMU. Matthew P. Zielewski, Ph.D. student in the Materials Science and Engineering (MASE) program at UTEP with a B.A. and M.A. in Physics, did an internship at CMU. His current research involves understanding how porosity forms in three-dimensional printed objects. The research looks at characterizing metallic powders to identify reasons why pores form in the final structure. Some of the factors to look at when analyzing powder are: density, oxidation on surface, irregularities, etc. The key points to identify are the size and grouping of pores in relation to print direction and height, as well as identify if there is any powder that did not melt during printing. In addition, Jose Veintimilla, who recently graduated from CMU with B.A. in Mechanical Engineering, worked at UTEP’s PNE lab during the summer. Jose was working on IoT (Internet of Things) enabled 3D printer with clay and

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Myocardial infarction (MI) is the irreversible necrosis of heart muscle, due to prolonged ischemia which leads to cardiac arrest due to arrhythmia. If not resuscitated within 24 hours after the occurrence of MI events, the tissue damage is irreparable.

Binata Joddar, Assistant Professor, is trying to solve this problem by fabricating cardiac tissue or simply a piece of the heart wall on a dish in the lab. Joddar heads and runs the Inspired Materials and Stem Cell Based Tissue Engineering Research laboratory (IMSTEL) at UTEP. One day, Joddar hopes to be able to engineer human cardiac tissue in a dish which will be vascularized and will resemble native cardiac tissue in its electrophysiology. Such lab engineered tissues can then be implanted directly in vivo or exploited in vitro for screening of drug related cardiotoxicity. Joddar holds a PhD in Bioengineering from Clemson University, following which she gained significant stem cell expertise during her post-doc training years in Riken and CiRA (Kyoto), Japan. Combining her expertise of working with naturally derived biomaterials and stem cell therapy, she hopes to achieve her goals of building a cardiac tissue on a chip in the future.

Stem cell therapy is a promising approach for myocardial infarction repair, and the use of stem cells to repair a damaged heart is now a reality in current cardiac research. Unfortunately, so far direct injection of stem cells into the fibrotic area of infarcted hearts has met with limited success, probably due to the low retention and survival of stem cells in the necrotic areas, together with the limited cardiogenic differentiation and functional integration of delivered cells within the host heart tissue. Joddar’s group will address these limitations with a new strategy, to design and optimize a tissue-engineered cardiac patch for delivering autologous adult human stem cell derived cardiac and vascular cells strategically layered and aligned within hydrogel scaffolds to repair the damaged myocardium.

Graduate student, Shweta Anil Kumar, conducting a bio printing experiment. Also, seen are high school students/summer interns, Ms. Avnika Tandon and Mr. Estevan Mesa in Inspired Materials and Stem Cell Based Tissue Engineering Research laboratory (IMSTEL).

Binata Joddar and her team visiting local high schools as part of outreach activities.

Recently, the work of Shweta Anil Kumar (PhD student in MASE program and working with Binata Joddar), has shown a pathway wherein 3D ‘bioprinting’ is being used to fabricate cell sheets containing human stem cells seeded in a density mimicking in vivo tissues. After printing, the structures are stabilized using post-crosslinking mechanisms and cultured in an incubator until they degrade in vitro. To their surprise, these structures are extremely stable on being tested for at least 5 days. Furthermore, the cells incorporated within these structures are viable and cross-communicate with each other by forming networks as they normally behave in vivo. Now her group is in the process of expanding this outcome by printing monolayer of tissues with one single cell type and then combining those monolayers to form a composite multilayered structure as seen in the heart wall, where many different types of cells namely, cardiomyocytes, endothelial cells and smooth muscle cells happily co-exist and function at the same time. However, there are several challenges to do this, as pointed by Binata Joddar, “First we need a bioreactor to keep our engineered thick heart tissues alive and functioning in vitro. Second, we must compare the engineered tissue structure and anatomy with native heart tissues for which they are in the process of initiating an animal study where MI or heart attack will be induced on rodent heart walls and tissue will be collected to assess the end points of MI and compare and contrast the structure with in vivo tissues.” Binata Joddar acknowledges NIH for supporting the research effort toward this end.

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Shape Memory Polymers by Additive Manufacturing: Expanding the usefulness and applicability of additive manufacturing through materials development has been the mission of David Roberson, Associate Professor in the Department. With strong focus on thermoplastics, Roberson’s research group has sought to expand the materials pallet available for the 3D printing technology of Fused Deposition Modeling (FDM), which is currently the most ubiquitous 3D printing platform and typically relies on common polymeric materials such as acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA). New 3D printable polymeric systems with enhanced electromagnetic, elastic, and shape memory properties are just a few of Roberson’s achievements.

A schematic representation of the phase reverted transformation concept to obtain nanograin structure.

Motivated by the success of the approach, the innovative concept was extended to microalloyed steels to obtain NG structure that was characterized by low temperature superplasticity. The experimental reports on superplasticity at low temperatures (<0.5Tₘ) are rare, and this is particularly true with low carbon microalloyed steels. Grain boundary migration occurred during plastic deformation, an attribute of grain boundary sliding associated with superplasticity, a significant finding in microalloyed steels.

The approach was considered suitable to fabricate ultrafine-grained stainless steel endoscopy treatment tool (diameter less than 0.7 mm) by modifying the process (repeated plastic deformation instead of one-step).

Grain boundary migration (indicated with arrows) in superplastic microalloyed steel.

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Multiaxial Forging of Mg-2Zn-2Gd Alloy Leads to Grain Refinement to Submicron Regime: Magnesium alloys have attracted significant attention for use in the automotive industry and for biomedical applications. The primary advantages of magnesium alloys from the perspective of automotive and biomedical applications are low density and good mechanical properties. The barrier that restricts the use of forged Mg and its alloys is limited formability because of limited number of active slip planes during deformation of hcp close packed crystal structures. As-cast and annealed samples were multiaxially forged (MAF) by Pramanshu Trivedi and colleagues, for a total number of two passes with a true strain of ~2/pass. Using only two passes, multiaxial forging successfully reduced the average grain size to less than ~1 µm. The mechanical properties of as-cast, annealed, and multiaxially forged (2 pass) Mg-2Zn-2Gd alloy were yield strength ~ 227 MPa and elongation of 30%. This combination of properties are excellent for the lean alloy.

The study of nanoscale deformation behavior indicated that in the ultrafine-grained alloy extensive dislocation slip was an active deformation mechanism, while in the coarse-grained counterpart, mechanical twinning occurred, implying that the grain structure strongly influences the deformation mechanism.

Titanium Alloy Porous Implants and Trials
The data suggests that metal orthopedic joint replacement (hip or knee joints) and bone plate surgeries now number in the millions worldwide annually, with knee joint replacement surgeries in the US alone numbering more than 300,000 annually. Most hip and knee implants are fabricated from wrought or cast bar stock by CNC, CAD-driven machining, or powder metallurgy (PM) production methodologies: including HIP and powder injection molding of near-net-shape components. Most of these millions of joint replacements, bone plates, etc. are generic, mass-produced components which do not work well with patients having an abnormal or unusual anatomy. In these situations, custom-designed implant components are preferred or required. This is also particularly true for cranioplasty especially where component to be fabricated to follow the overall skull curvature. A further challenge in implant component fabrication is the necessity to manufacture complex shapes, including thin-walled sections, where cutting operations can take a long time owing to significant material removal; up to 80% of bar stock from which knee implants are fabricated is converted to metal chips or scrap material.

In this context, additive manufacturing (AM) utilizing laser or electron beam melting reduces the need for tooling such as molds and jigs, although AM can fabricate more optimized and complex patterns than metal and alloy casting; especially applicable in automotive, aerospace, electronic and medical/biomedical (including dental) product manufacturing. Complex monolithic geometries involving little or no joining operations accommodating rapid design changes enable flexible production and mass customization strategies using AM technologies involving laser and electron beam processing of pre-alloyed powder beds by incremental (layer) manufacturing.

Devesh Misra’s group together with Larry Murr and Krishna Nune is collaborating with the Institute of Metal Research, Chinese Academy of Sciences and Department of Orthopedics, Xijing Hospital, Fourth Military Medical University, Xi’an, China to evaluate the performance of titanium alloy structures with different unit cells in terms of impact loading, fatigue, and biological functions.

A variety of open-cellular titanium alloy (Ti-6Al-4V) implants, both reticular mesh and foam structures were successfully fabricated using electron beam melting (EBM). These structures allow for the elimination of stress shielding by adjusting the porosity (or density) to produce an elastic modulus (or stiffness) to match that of both soft (trabecular) and hard (cortical) bone. Three-dimensional porous structures had the added benefits of promoting cell-cell contact, cell-matrix interactions, and the possibility of obtaining an efficient blood vessel ingrowth and enhanced oxygen, nutrient and waste flow. They were made bioactive via micro-arc oxidation (referred as plasma electrolytic oxidation) to form a thin layer of bioactive titania on the surface and through the growth of titanium nanotubes via an electrochemical process. An outcome of the study addressed the challenges associated with the treatment of segmental bone defects and bone-remodeling and provided a foundation for practical application of bioactive 3D printed interconnected porous architecture.

Animal (sheep) and human trials for electron beam melted (EBM)-fabricated, and patient-specific titanium-alloy implants are being conducted. The results, while preliminary, support the concept and development of successful, porous, engineered “living” implants. To our understanding, human trials of other manufactured orthopedic appliances have been performed by the U.S. Army Medical Center.

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Illustrated here is the surgical planning and results for a customized Ti-6Al-4V pelvic tumor and acetabulum reconstruction and prosthesis design by EBM fabrication for a 35-year-old male. The prosthesis was designed to eliminate stress shielding and optimize bone cell ingrowth using an open-cellular structure.

Selected Publications: During the academic year 2016-17, a record number of more than 50 peer-reviewed papers were published by the students and faculty. The citations of published research were high at about 1500 in 2016.

The students and faculty are engaged in cutting edge original and interdisciplinary research. While pursuing research, students become competent in logical thinking and acquire experience and skills in using advanced scientific instrumentation. They become trained in a manner such that they can keep their career options open and have the ability to switch career tracks at the beginning of and throughout their professional lives.

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