NSF Engineering Research Center for
Revolutionizing Metallic Biomaterials
NC A&T State University
University of Pittsburgh
University of Cincinnati
Hannover Medical School

NEWSLETTER winter 2009-2010

Published by the ERC-RMB Student Association **VOLUME 1, ISSUE 1**

A MESSAGE FROM THE DIRECTOR: DR. JAGANNATHAN SANKAR

It gives me great pleasure to welcome the readers to this very first newsletter of the Engineering Research Center for Revolutionizing Metallic Biomaterials (ERC-RMB). The whole premise of our Gen 3 ERC is to transform current medical and surgical treatments by creating "smart" implants to improve treatments for orthopedic, craniofacial and cardiovascular ailments coupled with the development of a vibrant, diverse workforce well-prepared for the multidisciplinary and global challenges and opportunities of the new millennium.

The ERC's kick-off year (2008-2009) has been very rewarding. The team worked hard on integrating research areas, educational and outreach activities and developing strategic partnerships with industries and global research leaders to rapidly advance a culture of innovation in the field of biodegradable materials. Our start-up activities and lessons learned have brought the entire team together to approach our multifaceted mission of research, education, and outreach for our second year and beyond in a seamless fashion between institutions and disciplines.

What is most gratifying is the way the student body of the ERC has moved forward in taking ownership of the Center. Kudos to them! This newsletter is just one product of the wonderful drive and dedication of the ERC students, our next-generation innovators and thinkers. It showcases some of our 2009 activities and sets the foundation to move forward in the coming years.

Again, welcome to our Center. I look forward to your feedback and participation as we strive to improve continuously.

Sincerely,
Jag Sankar
sankar@ncat.edu
ERC Center Director

GREETINGS FROM THE STUDENT ASSOCIATION

Welcome to the inaugural issue of the student-produced ERC-RMB Newsletter! Since being established in late 2008, student membership and participation in the ERC has increased in the past year to now include 37 student members. A strong student body is emerging to help guide the ERC towards becoming a mature and productive entity.

We hope that this quarterly publication will capture the highlights of our ERC activities and the accomplishments of our personnel. The co-editors, Da-Tren Chou of the University of Pittsburgh and Mitesh Oswal of the University of Cincinnati, deserve special recognition. In this issue, our summer activities are summarized, including summer research programs and our Student-Faculty Retreat, at which new members of the student association were appointed to the Student Leadership Council. In the Fall, our ERC participated in a number of scientific meetings. Additionally, we have made substantial progress in each Engineered System (ES), a portion of which will be detailed in every issue. We also plan to include Student, Faculty, and Industrial profiles, to acknowledge individuals within our ERC.

We are moving full steam into 2010, and we look forward to another productive year through the hard work of the many people committed to making this ERC a success.

See you in the Spring Issue!

Chris Smith
North Carolina A&T (NCAT)

Amos Doepke
University of Cincinnati (UC)

Matt Fisher
University of Pittsburgh (Pitt)

SLC Co-Presidents

Inside this issue:

About the ERC-RMB

The vision of this ERC is Revolutionizing Metallic Biomaterials and the underlying technologies.

This will lead to engineered systems that will interface with the human body to prolong and improve quality of life.

The ERC's strategic research plan has three engineered systems that will be driven by enabling technologies. The engineered systems are Craniofacial and Orthopedic Applications (ES1), Cardiovascular Devices (ES2), and Responsive Biosensors for Implants (ES3).

ERC Student Association at the Student-Faculty Day.

SUMMER RESEARCH WITH DR. WITTE

During the Summer of 2009, Pitt undergraduate Paul Shin and I had the opportunity to work with Dr. Frank Witte at CrossBIT at Hannover Medical School (MHH) in Hannover, Germany. I contributed to a project that evaluated the efficacy of various implant coatings for transcutaneous implants. The end goal of my project was to improve bone-anchored transcutaneous implants so that amputees could use such implants as anchors for prosthetics.

We examined four implant coatings: polished titanium, hydroxyapatite, and oxygen and hydrogen-terminated nanocrystalline diamond coatings. My primary responsibility was to segment and analyze OCT images of transcutaneous implants in mice. I wrote an ImageJ plug-in which segmented the images and measured various tissue healing parameters around the implant. The project is still being conducted at CrossBIT and my plug-in is still being used.

The summer was a great opportunity to experience the culture of Germany as well as Europe as a whole. The people of Hannover were very friendly and helpful with the transition into German culture. We quickly made many friends with students at the medical school who included us in their social outings. We also traveled with our new friends to Paris, Amsterdam, Berlin, Hamburg, and other destinations. We further enjoyed the largest Schützenfest in the world and the Maschsee Festival.

- Contributed by Frank Petraglia (Pitt)

A visit to Notre Dame Cathedral was a highlight of Mr. Petraglia's international experience.

NANO-TO-BIO SUMMER CAMP

Students learned of extracellular matrix, mechanical properties of tissues, wound healing, and the structure and function of skin.

This summer, four Pitt students (Andrew Brown, Amy Chaya, Garrett Jeffries, and Trisha Pavel) visited NCAT and served as counselors along with NCAT undergraduate Jason Bartlett for the "Nano-to-Bio Summer Camp". Pitt professor Dr. Steven Abramowitch and local high school biology teacher Ray Schrader teamed up with Dr. Cindy Waters from NCAT to organize and facilitate the week-long day camp.

The ERC-funded tissue engineering (TE) camp introduced seventeen local high school students to TE by providing them with hands-on laboratory experiments, guest presentations, and NCAT laboratory tours. These activities not only introduced students to important laboratory equipment, techniques, and skills, but offered new and unique opportunities they may not have otherwise encountered.

The students' overall reaction to the camp was overwhelmingly positive. Students left the camp with a more comprehensive understanding of TE, experience with TE-related experiments, and an improved understanding of the many exciting science and engineering career options. The program was so successful that it was featured by the local news media (http://www.myfox8.com/_news/wghp-wrwos-tissue-engineering-090730,0,846402.story). Plans for next year's camp include updating the activities based on student feedback, as well as increasing the number of young scientists.

- Contributed by Amy Chaya (Pitt) and Andrew Brown (Pitt)

ES3 GROUP FROM UNIVERSITY OF CINCINNATI VISITS PITT

ES3 members visited the University of Pittsburgh on October 28, 2009. The agenda of this visit was to present some of the research currently being done by University of Cincinnati (ES3) and University of Pittsburgh (ES1 and ES2) and to visit the laboratories there.

The first presentation was given by Dr. David Schmidt (Pitt) on 'Predictive Models for Metallic Bioadsorbable Stent-Tissue Interaction' where he talked about how computational methods can be used to predict biofunctionality and biocompatibility of metallic vascular stents. The second presentation was given by Dr. Thomas Gilbert (Pitt) on 'Degradable Metals in Pediatric Cardiothoracic Surgery' and emphasized the interest in regenerating different portions of the trachea. The next presentation was by Dr. William Wagner's post-doctoral fellow, Dr. Sang-Ho Ye (Pitt), who presented his work on 'Non-thrombogenic Surface Modifications for Metallic Blood Contacting Devices'. Ye talked about constructing a hemocompatible interface on a metallic surface. Dr. Charles Sfeir (Pitt) then discussed work going on in ES1 and ES2 which included the alloy designs and in vitro assessment of the alloys.

Dr. Heineman from ES3 provided a presentation on his lab at University of Cincinnati. He explained his in-vitro test beds for monitoring degradation of implant materials and also provided some results from experiments conducted by his group. There were a few parameters from his results which were discussed which eventually could be used for computational modeling for the research going on at Pitt.

Continued on page 3

Robotic testing system to assess knee joint function at the MSRC led by Dr. Savio L-Y. Woo.

Continued: ES3 VISITS PITT

The second half of the visit involved touring the labs at Pitt. Dr. Huinan Liu and Mr. Matt Fisher led a tour of the Musculoskeletal Research Center (MSRC). They provided information on various biomechanical research experiments conducted in the lab. Dr. Xiliang Luo (post-doctoral fellow with Dr. Tracy Cui) led a tour of Dr. Cui's lab. Lastly, Dr. Sfeir gave a tour of the Center for Craniofacial Regeneration showing various experiments conducted, including the Bioreactor flow device used for cell culture.

- Contributed by Mitesh Oswal (UC)

STUDENT-FACULTY DAY

The first ERC-RMB Student-Faculty Day was held in Greensboro on August 23-24, 2009. The event was attended by more than 35 ERC students together with 30 ERC faculty and staff members. The goals of the Student-Faculty Day were to:

* Introduce students and faculty and form positive relationships.
* Develop a common "ERC knowledge base" for all students.
* Nominate new members to the Student Leadership Council, form subcommittees, and define objectives/action items for the next year.
* Obtain feedback from students on how to improve the ERC.
* Discuss current ERC research and plan next steps.

The event kicked off on Sunday afternoon, with the RMB Student Association holding a Planning Meeting to discuss the current status and plans to move forward. We are happy to announce that many positions on the Student Leadership Council were filled! Action items for the Student Association were developed, which were then presented to the students and faculty the next day.

After a few hours of work, it was time to relieve some stress, so the students hit the bowling alley with some brave faculty members.

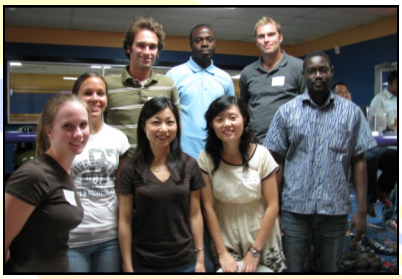
Early next morning, it was back to work. The morning sessions provided an overview of the ERC and its Engineered Systems, followed by student presentations on the latest ERC research. The morning concluded with a discussion of industrial partnerships by Mr. Wayne Szafranski (NCAT) and a short summary of the ERC action items by the SLC Co-Presidents.

After lunch, the discussions moved toward the near future. Dr. Harvey Borovetz (Pitt) and Dr. William Wagner (Pitt) led a summary of the NSF Site Visit last May, and discussed new initiatives for the upcoming year to improve our ERC. Then, parallel sessions were held on "Accelerating ERC Research" and "ERC Educational Development". Both sessions were used to engage students and faculty to solve current challenges and allow significant progress to be made.

Finally, individual ES sessions were held to allow smaller groups to chat about more specific research and organizational topics in an informal setting.

Following these meetings, most ERC members departed to begin the work discussed at the Student-Faculty Day.

- Contributed by Matt Fisher (Pitt)



ERC members enjoy some physical fitness after a long day of constructive meetings.

ENGAGING THE NEXT GENERATION WORKFORCE IN THE EXCITEMENT OF STEM

During its first year, the ERC-RMB's Education and Outreach programs cast a wide net to reach and excite a diverse audience from all academic levels, including community college and university systems, as well as to parents and the lay community.

Undergraduate ERC students from NCAT were joined in the summer by twelve students recruited from partner and regional institutions for a six week Research Experience for Undergraduates (REU) program as well as by five teachers from community colleges and school systems in the Piedmont Triad Region of North Carolina for a Research Experience for Teachers (RET) program. Participants attended enrichment seminars, visited local industries, and the teachers received instruction on development of effective learning modules delivered by a subject matter expert, Ms. Shawn Watlington of Guilford County Schools.

REU students and RET teachers working in clean room facility at NCAT .

In 2009, ERC students and staff were active in visiting local schools for the Science, Technology, Engineering, and Mathematics (STEM) Education Coalition, serving over 400 elementary, middle and high school students at their home schools or at local workshop/competition venues, as well as hosting students, teachers, and family members connected with schools throughout North Carolina.

Underrepresented populations were reached through strategic partnerships with the North Carolina Louis Stokes Alliance for Minority Participation (NC-LSAMP) and the Alliances for Graduate Education and the Professoriate (AGEP) program. At NCAT, a daylong STEM camp for Girl Scouts and the Nano-to-Bio Camp were conducted. All the outreach events received effective and positive media coverage.

Furthermore, dozens of NCAT, Pitt, and UC ERC students and faculty participated in the October 2009 Biomedical Engineering Society (BMES) Annual Meeting in Pittsburgh. In the fall of 2009, NCAT and UC students made good use of the cyberinfrastructure by taking the Pitt-led course entitled Principles of Cell Biology for Engineers along with modules on creativity and innovation.

- Contributed by Dr. Devdas Pai (NCAT)

2009 Summer Program Awards Ceremony at NCAT.

BIOMG09 CONFERENCE

The BioMg09 conference was organized by Dr. Veselin Shanov and Dr. Frank Witte and held in Greensboro, NC on November 6-7, 2009. The meeting brought together faculty and students of the ERC with our industrial partners in the health sciences and materials processing fields from the U.S., Germany, and Canada. After a brief introduction from Vice-Chancellor Radha and Dean Winser Alexander of NCAT, the industrial guests were given an overview of the ERC by Dr. Sankar and an introduction to each ES by Drs. Prashant Kumta (Pitt), William Wagner (Pitt), and Mark Schulz (UC).

In the afternoon, the state-of-the-art in magnesium (Mg) research was presented. A few members from GKSS (Germany's federally funded research facility equivalent to the U.S. Department of Energy facility, NETL) gave talks on the mechanical properties, corrosion, in-vitro and in-vivo degradation properties, and other in-vitro studies of magnesium alloys. Dr. Frank Witte (MHH) then gave a presentation on his extensive research on the in-vitro and in-vivo evaluation of Mg alloys. Invited speaker Dr. Diego Mantovani (Université Laval) summarized his work on the use of degradable metals for cardiovascular applications. Finally, invited speaker Dr. Elhachmi Essadiqi discussed the Mg-related activities at CANMET-MTL. Throughout the day, free time was available so that potential collaborations between individual ERC and industrial members could be explored.

A dinner followed at which the strategic plan of the ERC was discussed, along with an update on project proposals. The next day, the industrial members were given a tour of the ERC facilities at NCAT.

- Contributed by Matt Fisher (Pitt)

Group photo of ERC members with invited guests at the BioMg09 Conference.

ENGINEERED SYSTEMS HIGHLIGHTS

This section includes a selected research highlight from each of the three Engineered Systems.

ES1: Craniofacial and Orthopedic Applications: *Development of MgZnCa Alloys*

Dr. Zhigang Xu from NCAT has designed two magnesium alloys of the composition: $Mg_{95.37}Zn_{3.98}Ca_{0.65}$ and $Mg_{90.76}Zn_{8.54}Ca_{0.70}$. The processing method used includes: 1) mixing the powders with shake milling, 2) compacting the powders into cylinders, 3) melting the powder mixtures and casting into steel molds inside a glovebox, 4) machining the alloys out from the mold, 5) thermal treating the alloys, 6) cutting the alloys into thin discs, 7) polishing the discs. The specimens are classified in three groups: 1) As-cast, 2) Solution treated - 400°C for 24h (T4), 3) Artificially aged T4 plus 48h heating at 120°C followed by cooling in the glove box (T6). Researchers at NCAT have designed a full spectrum of study for these materials, such as characterizations of phase and phase transformation, microstructure, mechanical properties, etc. - Contrubuted by Dr. Zhigang Xu (NCAT)

ES2: Cardiovascular Devices: *Non-thrombogenic Surface modifications for Metallic Blood Contacting Devices*

ES2-1 is developing innovative surface modification technologies that can reduce thrombogenicity on metallic blood contacting cardiovascular devices. To construct a stable and hemocompatible biointerface on a metal surface ($TiAl_6V_4$ or magnesium), we are focusing on introducing hemocompatible moieties (focused on zwitterionic phosphorylcholine (PC) or sulfobetaine (SB) groups) covalently on metallic surfaces. Furthermore, a silanated functional PC or SB surface modifier recently prepared for simple surface modification on a metal surface will be applied on a magnesium surface directly or indirectly to improve the surface blood biocompatibility. Blood compatibility evaluation and comparison studies will be performed with other different coating surfaces. - Contributed by Dr. Sang-Ho Ye (Pitt)

ES3: Responsive Biosensors for Implants: *Magnesium and Carbon Nanotube Based Materials for Implant, Biosensor, and Scaffold Applications*

Early experiment results indicated that substantial increase in the purity of Mg dramatically decreases its corrosion rate. Agglomerates of high purity single crystals (crystallites) and individual single crystals of Mg reveal reduced corrosion rate and appear to be promising materials for biodegradable implants. ES3-4's near future plans include: (1) Complete the "Generation 2" PVD/CVD facility for manufacturing of Mg based materials (coatings and 3D crystals); (2) Produce optimized and free standing 3D Mg crystallites (up to 10 mm in diameter) with high purity and increased corrosion resistance; (3) Produce optimized coatings of micro-single crystals with high purity and increased corrosion resistance deposited on 4 square cm silicon (Si) 4 wafers; (4) Fabricate MgO nanowires on Si wafers with an area of 4 square cm for cell culture experiments (in collaboration with Dr. Frank Witte (MHH)). - Contributed by John Yin (UC)

ERC MEMBER PROFILES

This section includes profiles of ERC faculty, students, and industrial partners.

Student Profile: Christopher Smith—NCAT

Chris Smith is a first-year graduate student at NCAT. After receiving his B.S. in Mechanical Engineering from NCAT in 2009, Chris stayed to pursue his Ph.D. in mechanical engineering, under the direction of Dr. Jag Sankar, Director of the ERC. Although Chris is just beginning graduate school, he has already focused on the processing of porous and non-porous magnesium (Mg) alloys. He has created Mg-Aluminum-Zinc (AZ91) and Mg-Yitrium (Mg-Y) alloys using a glove box in the facilities at NCAT. Then, he sintered these samples using a hot iso-static press, and used scanning electron microscopy and X-ray diffraction to assess their chemical and physical composition. In the future, these open pore Mg alloys can be processed further for orthopedics, craniofacial, and cardiovascular applications. For example, Chris hopes to set up a hot-extrusion device to make Mg alloy wires for stent applications.

Innovation Partner Profile: The Ex One Company

The Ex One Company LLC is a privately held enterprise headquartered in Irwin, PA with seven facilities around the world. The company offers equipment and contract services in commercialization of their advanced technologies. One such technology is pulse laser machining, which is used to drill holes (as small as 300 μm) in parts such as fuel injector nozzles. The equipment has also been used experimentally to machine vascularity molds for liver implants.

For the Revolutionizing Metallic Biomaterials ERC, the Ex One technology of interest is its 3D printing process for rapid manufacturing. Licensed from MIT for exclusive use with metallic and ceramic materials, the process involves spreading a thin layer of powder (as thin as 50 μm) and then rastering a piezo-activated, 128-jet printhead that deposits binder droplets onto the powder at locations defined by a 2D slice of the 3D part to be produced. The binder droplets are approximately 50 microns in diameter with a volume of 125 picoliters. Each droplet impinging on the powder layer agglomerates powder particles by surface tension into a voxel (3D pixel) that is about 75 μm by 75 μm by 100 μm in size.

Repeating this process layer after layer produces a 3D part defined by a CAD solid model. After printing, the part must be sintered to the desired density or lightly sintered and then infiltrated with a lower melting point material. Of particular interest is the process capability to produce parts with internal holes or channels that cannot be produced by conventional shape-making process. In addition, the process produces one-of-a-kind parts, such as medical implants and scaffolds based on MRI or CAT data.

The 3D printing process is in commercial use for the production of stainless steel/bronze art and architectural pieces (up to 1200 mm in size), tooling with conformal cooling channels for injection molding of polymers, patternless sand molds (up to 1500 mm in size) for casting metals, and precious and non-precious metal copings for crowns (Figure 1). Through a recent project in the ENGR 1050 Product Realization course at the University of Pittsburgh, a student team used a dental version of Ex One's 3D printer to produce prototype scaffolds of unalloyed Mg (Figure 2). Thermal processes are being explored to convert the printed material into parts with structural integrity.

- Contributed by Dr. Howard Kuhn of Ex One

Figure 1. Scanned die, 3D printed gold alloy coping, and finished crown.

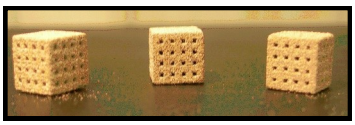


Figure 2. Prototype unalloyed Mg scaffolds produced by 3D printing.

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1601 E. Market Street
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Visit us on the web!

ERC Homepage: **http://erc.ncat.edu/**
Student Association: **http://www.rmbsa.org/**

CONTACTS

Director: Dr. Jag Sankar
(336) 256-1151 ext. 2282
sankar@ncat.edu

Executive Director: Dr. Harvey Borovetz
(412) 624-4725
borovetzhs@upmc.edu

Administrative Director: Ms. Lois Deve
(336) 334-7995 ext. 2006
lddeve@ncat.edu

ES1 Leader: Dr. Prashant Kumta
(412) 648-0223
pkumta@pitt.edu

ES2 Leader & Deputy Director: Dr. William Wagner
(412)624-5324
wagnerwr@upmc.edu

ES3 Leader & Deputy Director: Dr. Mark Schulz
(513) 556-4132
mark.j.schulz@uc.edu

Education & Outreach Director: Dr. Devdas Pai
(336) 256-1151 ext. 2106
pai@ncat.edu

Global site coordinator: Dr. Frank Witte
+49-(0)511-5354-546
f.witte@web.de

Industrial Liason: Mr. Wayne Szafranski
(336) 256-1251
waszafra@ncat.edu

Newsletter Editors: Mr. Da-Tren Chou & Mr. Mitesh Oswal
(440) 570-5876
dac105@pitt.edu, oswalmb@email.uc.edu

IN THE NEXT ISSUE

- NSF ERC Annual Meeting in Bethesda, MD
- ES Highlights
- ERC Member Profiles
- And much more...

ERC members at the Student-Faculty Day.

UPCOMING EVENTS

ES Teleconference Meetings– held weekly by each ES

Meeting of the Industrial Advisory Board & Scientific Advisory Board (Greensboro, NC)- March, 2010
National Educators Workshop (Greensboro, NC)- March 7-10, 2010
NSF Site Visit (Greensboro, NC)- May 25-26, 2010
2nd Symposium on Biodegradable Metals (Maratea, Italy)- August 31-September 3, 2010