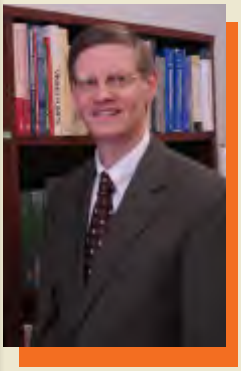
SPRING 2011

CLEMSON
CHEMICAL AND BIOMOLECULAR ENGINEERING



Message from the Chair:

Dear Alumni and Friends of the Department:

This past academic year was another successful one, filled with many significant student and faculty accomplishments. It was also a year for planning for the future. During the Fall semester, every Department at the University was visited by the three mission VPs – VP for Academic Affairs and Provost, VP for Research, and VP for Economic Development – for the expressed purpose of assimilating Departmental strengths, weaknesses, opportunities, and threats; aligning strengths and opportunities across campus; and, with President Barker, developing a plan to re-shape the University over the next decade.

In February President Barker rolled out CU Plan 2020, which calls for investments in four strategic areas:

- Enhance student quality and performance
- Provide engagement and leadership opportunities for all students
- Attract, retain, and reward top people
- Build to compete — facilities, infrastructure, and technology

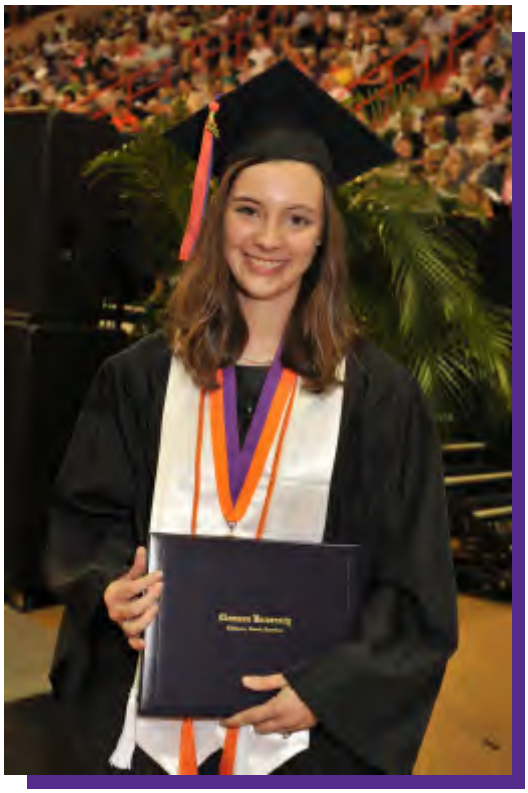
The plan also calls for aligning our research and educational programs with national priorities on energy/environment, health, and transportation, with cross-cutting foci on advanced materials and computing and information technology. It is noteworthy that the Department's research expertise covers all of these areas.

The College of Engineering and Science is now in a process to develop a proposed plan for faculty hiring over the next several years to support CU's stated priorities. We fully expect that Chemical & Biomolecular Engineering will benefit from this plan as we move to strategically grow the Department, and we will keep you posted on our progress.

Have a great summer!

Best regards,
Douglas Hirt, Professor and Chair

Jennifer Moffitt Awarded Norris Medal



At commencement on May 13, 2011, Clemson University's Norris Medal was awarded to ChBE senior Jennifer Moffitt. The Norris Medal was established under the terms of the will of D.K. Norris, a life trustee of Clemson. The medal is given each year to the graduating student who is judged to be the best all-around by the university scholarships and awards committee.

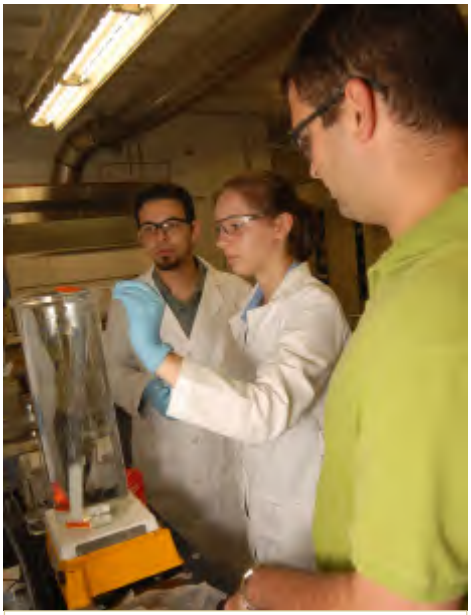
Jennifer, from Spartanburg, SC, was also the recipient of a prestigious Barry M. Goldwater Scholarship and the Eastman Award for Excellence in Chemical Engineering. She participated in the Honors College EUREKA! summer research program and studied abroad at the University of Sussex, England, and in Belize, Southeast Asia, and The Netherlands.

She is a member of Tau Beta Pi and Alpha Lambda Delta Honor Societies and participated in Women's Glee, CU Symphony Orchestra, and Women in Science and Engineering.

She conducted undergraduate research entitled "Phase Behavior of Cellulose Nanocrystal Dispersions" with Professor Christopher Kitchens and earned Calhoun College Honors. Her many community service activities have included teaching science and research to students at R.C. Edwards Middle School, Pickens County Election Poll Manager, co-coordinating Seismic Semi-formal to raise money for Haitian earthquake victims, and teaching safe behaviors to Clemson Freshmen.

Jennifer has accepted a position in Research and Development at the Eastman Chemical Company and plans to pursue a Ph.D. in Chemical Engineering while working.

Nanocomposites Derived From Renewable Resources: Mimicking Nature in the Design of Sustainable Materials



Esteban Ureña, Jennifer Moffitt, and Dr. Christopher Kitchens study their test methodology.

Dr. Kitchens' research lies at the interface of Nanotechnology and Green Engineering. The primary distinction of Nanotechnology lies in the fact that many materials possess unique properties when their dimensions are restricted to less than 100 nanometers in length. These properties run the whole gamut of the materials world, from unique catalytic or optical properties to extremely high strength-to-weight composites. The primary motivation is to understand the nanoscale phenomena that control these properties and develop new synthesis and processing methodologies that lead to new advanced materials. Simultaneously, we focus on the principles of Green Engineering to ensure that our methods are effective and lead to a sustainable future. One project in particular takes a few cues from nature in order to design polymer nanocomposites that have process tunable properties. In our lab, we have isolated crystalline particles of cellulose from cotton linters or a loblolly pine Kraft pulp and used these rod-shaped nanoparticles as a nanofiller for polymers derived from renewable resources. These isolated cellulose nanocrystals (CNCs) are elongated nanoparticles with an average length of 130nm, width of 20.4nm, and height of 6.8nm, as determined from AFM and shown in Figure 1.

Cellulose is the most abundant polymer on the planet and all forms of cellulose contain crystalline cellulose, which can be isolated by controlled acid hydrolysis. In general, the size and orientation of CNCs varies within different species of plants and leads to different properties on cellulose fibers. For example, the crystalline cellulose components of hemp or ramie bast fibers are highly aligned and have a low microfibrillar spiral angle with respect to the fiber axis, while cotton has a higher microfibrillar spiral angle (MSA). As a result, bast fibers have a high tensile modulus while cotton has a higher elastic modulus. A high MSA is also found in juvenile wood which requires more elastic properties while a low MSA is found in mature wood that must be stronger to support the weight of the tree. This relationship between the natural fiber mechanical properties and the nanoscale structural orientation of cellulose crystals, specifically the MSA, is of significant interest from a polymer nanocomposite processing standpoint because it lends opportunity to control fiber mechanical properties by tailoring the self-assembly of nanoparticles within the polymer matrix. We have recently demonstrated the appearance of this structure-property relationship in CNC reinforced alginate fibers. By controlling the CNC weight fraction loading and the fiber wet-spinning properties, we can tailor the mechanical properties that correlate directly with the CNC spiral angle within the alginate fiber.

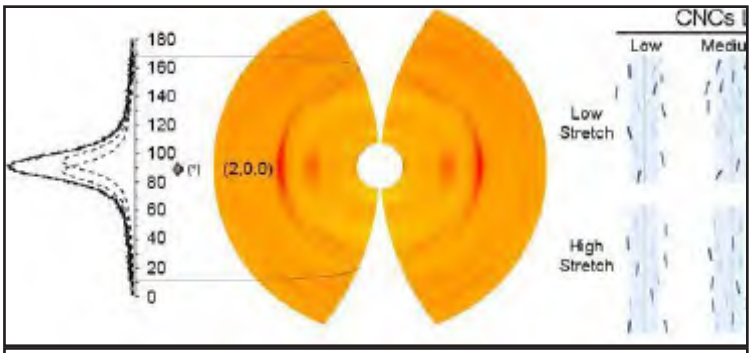


Figure 2. *The microfibrillar spiral angle (MSA) can be determined from the 2-D wide angle X-ray diffraction pattern by isolating the cellulose I (2,0,0) peak and measuring the offset angle from two equivalent deconvoluted Gaussian peaks. The MSA is shown to increase with CNC loading and decrease with fiber stretching during spinning, which also correlates with the fiber mechanical properties.*

Alginate fibers have found many applications such as the preparation of dressings to treat exuding wounds, drug delivery, enzyme immobilization, etc.; however their use is limited due to their poor mechanical properties. Cellulose nanocrystals (CNCs) were isolated from cotton and introduced into calcium alginate fibers with the goal of improving their strength and modulus. The CNCs were mixed with an aqueous sodium alginate dope solution, and wet spun into a CaCl2 bath to form fibers [1]. It was found that when the apparent jet stretch (ratio of the fiber draw velocity to extrusion velocity) is kept constant, addition of the nanocrystals reduces the tensile strength and modulus of the material; however a small concentration of CNCs in the dope solution increases the toughness and enables an increase in the fiber spinning apparent jet stretch ratio by nearly two fold at up to 25% CNC loading; the maximum jet stretch ratio of 4.6 is observed at 25%wt CNC loading, as compared to a maximum of 2.4 for the native alginate. Mechanical testing showed a 38% increase in tenacity and a 123% increase in tensile modulus with 10%wt CNCs loading and an apparent jet stretch of 4.2.

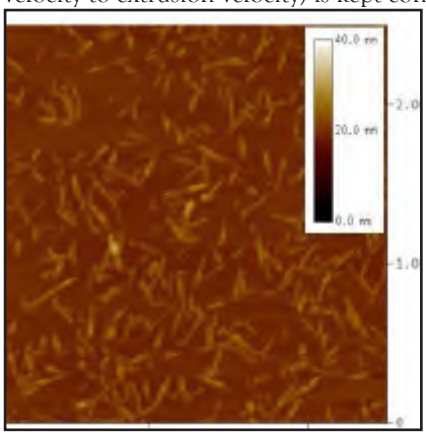


Figure 1. *Atomic Force Microscopy (AFM) image of CNCs isolated from a Kraft pulp obtained from a South Carolina pulp and paper mill. Image dimensions are 2.5 x 2.5 μm.*

Wide angle X-ray diffraction (WAXD) was used to determine the structure and orientation of CNCs within the alginate nanocomposite fibers and provide correlations with the resulting mechanical property enhancements [2]. The orientation of the CNC was determined from the azimuthal intensity distribution of the (2,0,0) reflection where the spread of the orientations increased with higher loads until the nanoparticles spiraled around the fiber axis. Increased fiber stretching retarded the appearance of a spiral assembly and increased CNC alignment, as depicted in Figure 2. A reduction of tenacity and modulus, and an increase in elongation at break and tensile energy to break coincided with the observation of the spiral orientation. These trends are analogous to those found in natural fiber and demonstrate our biomimetic design of CNC nanocomposite fibers.

[1] Ureña-Benavides, E. E.; Brown, P. J.; Kitchens, C. L. Langmuir 2010, 17, 14263-14270
[2] Ureña-Benavides, E. E.; Kitchens, C. L. Macromolecules 2011, 44 (9), 3478–3484

FACULTY HIGHLIGHTS

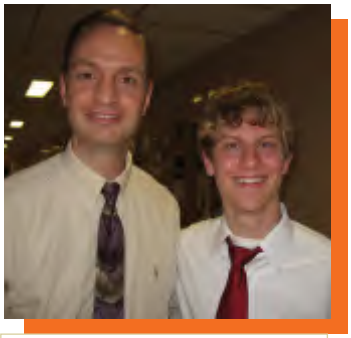
Prof. Anthony Guiseppi-Elie, was a keynote presenter at the 2011 International Conference on Frontiers of Characterization and Metrology for Nanoelectronics, May 23-26, 2011, MINATEC Campus in Grenoble, France. His talk was entitled "Frontiers of More than Moore in Bioelectronics and the Required Metrology Needs." He has also been named to the Board of Directors of the Council for Frontiers of Knowledge (CFK).

Professors Scott Husson and Chris Kitchens have received a 3-year grant from the National Science Foundation to run a 10-week summer research experience for undergraduates (REU) program for a talented and diverse group of undergraduates from across the nation. The intellectual focus of this REU site is Advanced Functional Membranes. The program will engage promising young students in research aimed at providing membrane-based solutions to grand societal challenges, from improving the quality and cost of healthcare, to producing a cleaner and safer environment, to improving materials for energy conversion and storage.

STUDENT HIGHLIGHTS

Jennifer Moffit and Allison Foreman present their National Scholars Progam's Awards of Distinction to Dr. Charlie Gooding.

Clemson's Robert J. Rutland Institute for Ethics held the 10th Annual J.T. Barton Jr. Ethics Essay Scholarship Competition, with this year's theme focused on the BP oil spill in the Gulf of Mexico. ChBE senior **Allison Foreman** was awarded third prize for her essay entitled, "What ethical obligations did BP have to protect workers like Ed when they were hired?"



Ray Smith with Dr. David Bruce on Graduation Day, May 13th.

Clemson's National Scholars Program (NSP) provides a full scholarship to about a dozen top undergraduates annually who have applied to the University. It is a rigorous application and selection process, including an on-campus interview. The Department graduated three seniors this past May who were members of the NSP – **Allison Foreman, Jennifer Moffitt, and Ray Smith.** Each year, the NSP invites seniors to present the National Scholars Program's Awards of Distinction to the faculty and advisors who have served as mentors in helping the students develop intellectually, professionally, and personally. Allison and Jennifer presented their awards to Professor Charlie Gooding.

ChBE junior **Adam Klett** was selected to receive a research fellowship from the Atlantic Coast Conference Inter-institutional Academic Collaborative (ACCIAC) – he was one of only three Clemson students selected this year. Adam works with Professor Mark Thies on a research project focused on the Sulfur-Iodine Cycle to split water into hydrogen and oxygen, for the purpose of producing hydrogen as a fuel on a massive scale as a replacement for petroleum-derived fuels. The ACCIAC Fellows Program in Creativity and Innovation supports undergraduate student-driven research projects at the Atlantic Coast Conference campuses.

Adam Klett working on his Sulfur-Iodine Cycle research project.

On the Honors and Awards Day in April, **Charles McGill** was awarded the Western S.C. Section AIChE Scholastic Achievement Award for the graduating senior with the highest scholastic average. For juniors, **Courtney Rowe** won the Dow Chemical Award; and sophomore, **Jeremy Kearns,** was awarded the 2010 Donald F. Othmer Sophomore Excellence Award. Congratulations to all!

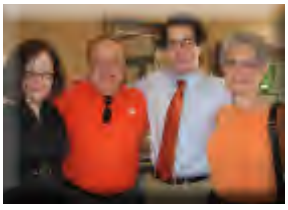
CLASS OF 2011

The Chemical & Biomolecular Engineering Department is proud to recognize the Senior Class of 2011. The students were honored at a Senior Reception on May 5th at the Madren Center, which was sponsored by Mansfield Oil Company out of Gainesville, Georgia. On graduation day, May 13th, the department hosted an Open House for the graduates and their families. The faculty and staff of ChBE want to wish all of our graduates the best of luck in all your future endeavors! Congratulations!

Dr. Esteban Ureña-Benavides on graduation day with his Ph.D. advisor, Dr. Chris Kitchens.

2011 Graduation Candidates
Bachelor of Science Degree
in Chemical & Biomolecular Engineering

Jason Michael Abel
Rafael David Alton
Terrance T. Barnes
Chad C. Carpenter
Coffin J. Chavous
Leslie E. Cheek
Kristin Marie Cook
Daniel R. Crandall
Johnathon A. Cribb
Colin Scott Cyr
Jonathan C. Decker
Addison Hughes Dill
Allison E. Foreman
Robert R. Fredeking
Luke J. Gledhill
Jennifer C. Graves
Phillip R. Harris
Donald J. Harter
Azikiwe T. Hooker
Michael L. Horton
Lorcan C. Ingham
William B. Johnson
Petra Kerscher
Jacob L. Lindler
Bradford Scott Long
Joseph M. Mannion
Rush Weber Marler
Michael D. Martin, Jr.
Charles J. McGill
Jonathan A. McKinley
Charlton A. Miller
Jennifer C. Moffitt
Jacob Daniel Morella
Eileen Q. Muckenhirn
Kenneth M. O'Connor
William Lane Patty
Mark Emile Pepin
Christopher Powell
John R. Powell III
Matthew G. Prewett
Robert A. Ramsbottom
Ruth Esther Sales
Elizabeth A. Savage
Raymond B. Smith
Rion Michael Sweet
William R. Sawyer
Charlotte V. Tyson
Stephen C. Vance
Hunter R. Watkins
Michael E. Westervelt



ALUMNI - CLASS OF 1963

Class of 1963 on a Field Trip to Olin-Mathieson Chemical Company in Brevard, North Carolina. Front Row (left to right): Dr. W.B. Barlarge, T.R. Kinard, A.D. Tolson, J.M. Clark, J. D. Rushton, W.H. Ponder, J.M. Harmon, L.B. Murdoch. Back Row (left to right): D.B. Watt, J.M. Brown, J.A. Goodson, J.B. Webster, J.N. Cromer, ?, W.H. Chelf, C.T. Hattaway, C.G. Hayes, C.H. Caban, G.F. Ruehling. Absent: J. I. Elsey, J.G. Richardson.

Standing in front of Earle Hall on May 20th were (left to right) Wade Ponder, Al Tolson, Jim Rushton, Cliff Hattaway, John Cromer, Jerry Richardson, and John Elsey. Attending but not available for this picture were Larry Murdoch, Terry Kinard, and Dr. Barlage.

The ChBE Class of 1963 held their Class Reunion at Earle Hall on May 19th and 20th. The reunion was organized by their fellow classmate, Dr. James Rushton. They had attendees from as far away as Montana. One of their Chemical Engineering professors, Dr. William Barlage, was also able to attend. Some of the attendees had not been in Earle Hall for over 48 years, so it was enjoyable looking at old pictures and reminiscing with classmates.

While they were here, they were able to tour our lab facilities and were updated on current research, renovations, and future goals by our Department Chair, Dr. Doug Hirt. They also were able to have an in-depth tour of the Athletic facilities on campus and other points of interest around Clemson during their stay.

It was a pleasure hosting the Class of 1963!! We hope to see you again next year!!

Dr. Barlage and John Elsey

Larry Murdoch and Jim Rushton

Terry Kinard

ChBE PROFESSIONAL ADVISORY BOARD

The Department of Chemical and Biomolecular Engineering is proud to recognize the following members of our department's Professional Advisory Board. We would like to acknowledge and thank them for their time, efforts, and expertise in helping us define and refine our future goals and objectives. Thanks again!

Hal Bouknight (Chair)
VP Corporate Accounts
Willbros Group Inc.
Houston, TX
B.S. 1974 - Clemson

Doug Haugh
Executive VP and CIO
Mansfield Oil Company
Gainesville, GA
B.S. 1994 - Clemson

Hunter Harris
Operations Director
MWV Specialty Chemicals
N. Charleston, SC
B.S. 1978 - Clemson
M.S. 1980 - Clemson

Gary Hayes
Global Process Platform Leader
Sealed Air
Technology & Innovation
Duncan, SC
M.S. 1989 - Clemson
Ph.D. 1993 - Clemson

Monty Heins
Technology Director
Oxygenated Solvents &
Performance Monomers
Dow Chemical Company
Deer Park, TX
B.S. 1986 - Clemson

Jackie Moxham
Principal Scientist
Global Regulatory Chemistry
Manufacturing & Controls
Pfizer Inc.
Groton, CT
B.S. 1992 - Clemson
M.S. 1994 - Clemson

Jennifer Peavey
Innovation Manager
Eastman Chemical Co.
Kingsport, TN
B.S. 1992 - Clemson
M.S. 1993 - Clemson

Mary Rezac
Professor & Co-Director
Center for Sustainable Energy
Dept of Chemical Engineering
Kansas State University
Manhattan, KS
B.S. 1987 - Kansas State
Ph.D. 1993 - Univ. of Texas

Johannes Roebers
Senior VP Biologics Strategy
Planning and Operations
Elan Pharmaceuticals
Dublin, Ireland
Ph.D. 1991 - Clemson

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Advanced Materials
Biosensors and Biochips
Chemical & Biomolecular Separations
Energy
Kinetics and Catalysis
Molecular Modeling and Simulation

PhD GRADUATES

Dr. Esteban Ureña-Benavides
Dissertation: **"Cellulose Nanocrystals Properties and Applications in Renewable Nanocomposites"**
Advisor: Dr. Christopher Kitchens
Current Position: Post Doc
Auburn University
Auburn, Alabama

Dr. Kitiya Hongsirikarn
Dissertation: **"Effect of Impurities on Performance of Proton Exchange Membrane Fuel Cell Components"**
Advisor: Dr. James Goodwin
Current Position: Research Analyst
Nexant Asia Limited
Bangkok, Thailand

Dr. Gregory White
Dissertation: **"Synthesis, Stabilization, and Characterization of Metal Nanoparticles"**
Advisor: Dr. Christopher Kitchens
Current Position: Post Doc
Sandia National Laboratories
Albuquerque, New Mexico