MECHANICAL PROPERTIES RESEARCH LABORATORY (MPRL)
http://mprl.me.gatech.edu/

2012-2013 Annual Report

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(also interfaces with AE, CEE, ECE, GTRI)

College of Engineering
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MPRL STATUS AND SUMMARY OF 2012-2013 ACCOMPLISHMENTS

The MPRL is an interdisciplinary laboratory that supports research and education programs primarily related to deformation and failure/reliability of structural materials. Principal activities of the MPRL include the measurement and modeling of the mechanical behavior of engineering materials, particularly deformation, fatigue and fracture processes. The MPRL has a direct impact on educational and research programs of the College of Engineering. In its role as an interdisciplinary umbrella organization for research in mechanical properties of materials, the MPRL provides a degree of coordination of equipment usage, training and maintenance that would otherwise be much more costly to the sum of academic units in the conventional university setting of distinctly controlled single investigator equipment. The MPRL has an international reputation for excellence in several areas:

- Fatigue and fracture studies of structural materials, structures, and joints/attachments, particularly in extreme environments including high temperature applications.
- Development of constitutive equations for deformation and damage, incorporating these advances into life prediction methodologies.
- Multiscale modeling and simulation of materials and microstructure-sensitive fatigue and fracture approaches, making contact with experiments to discern mechanisms and validate models and methodologies, both deterministic and probabilistic (e.g., supporting the NSF Center for Computational Materials Design, Integrated Computational Materials Engineering (ICME), and Materials Genome Initiative (MGI)).
- Characterization and quantitative analysis of microstructure and damage in engineering materials such as structural alloys, composites, metal foams, thin films, biomaterials and nanostructured materials and alloys.
- Durability and degradation of aging materials and structures.

Participating faculty (20) and students are drawn principally from ME and MSE (Appendix A). The MPRL is administered by the Director. MPRL staff during the past year included Richard C. Brown (Research Equipment Specialist), who retired in October 2012, and ¼ time Research Engineer J.D. Huggins. Mr. Brown continues to assist as-needed through a consultant agreement to facilitate the transition of full responsibilities to J.D. Huggins. The plan is for J.D. Huggins to increase his time commitment to MPRL as his other appointment with Professor Emeritus Wayne J. Book winds down.

A listing of MPRL facilities can be found at http://mprl.me.gatech.edu/facilities/, summarized as:

- Tensile, compression, and bending test facilities
- Fatigue crack initiation and growth testing
- Fracture toughness testing
- Small scale testing laboratory
- High temperature testing (TMF)
- Drop weight impact tester
- Fretting test rig
- Instrumented indentation

- Thermal aging and creep facilities
- High strain rate facility (gas gun and split Hopkinson bars)
- Specimen preparation and image analysis

In addition, SEM, TEM and surface analysis facilities are available to MPRL faculty through the GT Institute for Electronics and Nanotechnology (IEN), the Center for Nanostructure Characterization and Fabrication (CNCF), and a SEM recently procured by new faculty S. Kalidindi. Various MPRL faculty members have access to computing clusters to pursue work at the interface of materials characterization, behavior and modeling.

Participating MPRL faculty members contribute to a wide range of courses in fatigue, fracture, deformation and damage of engineering materials, mechanics of materials, quantitative image analysis and nondestructive evaluation, materials selection and design, and mechanical behavior of materials. A graduate multidisciplinary certificate in the Mechanical Properties of Materials is also offered through the MPRL. It is estimated that over 20 graduate students were involved during the past year in MPRL-related research.

MPRL accomplishments from July 1, 2012 to June 30, 2013 are summarized in the Table below, with 16 of 20 MPRL faculty responding, 14 of whom stated that they had some level of research activity within the MPRL during the past year.

# Faculty Reporting Funded Activity	Published Refereed Papers	# Funded Projects	Students Graduated M.S.	Ph.D.	Faculty & Student Honors /Awards
14	79	31	3	8	10

Active MPRL faculty reported 113 conference presentations and seminars during this period. Approximately $2.44M was expended in externally sponsored research during the past year on projects related to MPRL facilities or thrusts, reported by MPRL faculty members. The distribution of per capita funding of the 14 faculty respondents this past year who were actively involved in MPRL research was as follows: at or above $300K (3), between $200-299K (1), $100-199K (5), $1-99K (5). We also handled two requests from non-MPRL-affiliated GT faculty who needed the use of MPRL equipment in their sponsored research programs. Those projects are not reported in these numbers.

Highlights

Administrative highlights of 2012-2013 included the following:

- The Dean of CoE appointed Rick Neu as the new Director of MPRL with the former MPRL Director, D.L. McDowell, becoming the Founding Director of the Institute for Materials.
- Chris Muhlstein, MSE faculty specializing in small-scale mechanical properties experiments, was appointed Associate Director.
- Successfully transitioned primary lab responsibility from R.C. Brown to J.D. Huggins with the retirement R.C. Brown in October 2012.
- Added two new participating MPRL faculty, S. Antolovich (MSE/ME) and S. Kalidindi (ME/MSE/CSE), both of whom have been active in the lab this past year and will continue to have activities in MPRL in the coming years.
- First floor of Bunger-Henry is becoming a world-class materials thermomechanical processing, mechanical properties testing and characterization facility with new lab spaces established by C. Muhlstein (MSE), S. Xia (ME), and S. Kalidindi (ME/MSE/CSE). All are establishing small-scale mechanical test and characterization facilities that complement the strengths of MPRL in larger scale mechanical property testing.
- Worked with ME, MSE, and CoE to house laboratories of new hire S. Kalidindi including consolidating his metallurgical preparation laboratories with MPRL in 2340 MRDC. S. Kalidindi acquired a SEM, fitted with an OIM system previously acquired by MPRL faculty, and a Raman Spectroscopy system. The systems are located in newly renovated 113 B-H and are accessible to MPRL researchers.
- Relocated the MPRL instructional lab that serves both MSE and ME from 113 B-H into a newly renovated instructional space adjacent to the MPRL research facilities, 153 B-H.
- Consolidated the aging and creep facilities to 173 B-H. Removed and surplused equipment no longer being used.
- Modified the Multidisciplinary Certificate in Mechanical Properties of Materials administered by MPRL to reflect changes that have occurred in this field of research and the course offerings since the last update well over a decade ago.

Research program highlights and development activities include:

- The Center for Computational Materials Design (CCMD), a NSF I/UCRC joint with Penn State, completed its 8th year in June 2013, and involves a substantial number of MPRL faculty (McDowell, PI/PD, Neu, Zhou, Gokhale, Garmestani, Zhu, and Kalidindi). A challenge to the CCMD is to increase membership, which has drawn down due to effects of the recent recession in terms of industry membership.
- The MPRL (Johnson, Neu, McDowell, Antolovich) completed its 6th year as a substantial component of the Pratt & Whitney/Georgia Tech Center of Excellence, serving as a preferred supplier of experiments and modeling related to advanced aircraft gas turbine engine materials (e.g., Ni-base superalloys).
- MPRL (Neu) completed its 7th year working with Siemens Energy Inc. on industrial gas

turbine structural integrity.

- Olivier Pierron received NSF CAREER Award.
- Steve Antolovich named Academician to World Academy of Structural Integrity.
- Ting Zhu received ASME Nemat Nasser Early Career Award.
- S. Xia received some gift money from the Haythornthwaite foundation to construct a 3D microscope for multiscale three-dimensional deformation and profile measurement which will be accessible to all MPRL faculty once the construction is complete.
- S. Xia received the Orr Early Career Award from ASME.

Plans for 2013-2014

- Ramp up training of J.D. Huggins on additional aspects of running lab through a periodic consultant arrangement with Mr. Brown. The support for Mr. Huggins, currently ¼ time at the start of the fiscal year, is anticipated to increase toward the mid-part of the fiscal year as his other support activity with W.J. Book winds down. During this transition period, it continues to be critical to hire Mr. Brown as a consultant to help bridge MPRL support.
- Work with the Founding Director of the Institute for Materials, D.L. McDowell, to make MPRL a strategic user facility in the Institute for Materials.
- Enhance cooperative laboratory relationships among affiliated labs housed in the Bunger-Henry building (i.e., Muhlstein, Xia, and Kalidindi).
- Develop expertise for Digital Imaging Correlation (DIC) aimed at displacement field measurements in MPRL through collaborations with several MPRL faculty (Antoniou, Muhlstein, Xia, Neu, Antolovich) and M. Mello in AE.
- Develop modules on strength and fracture toughness in the renovated instructional center of MPRL under development by O. Pierron for a summer enrichment program for high school students, closely coordinated with the large NSF "amp-it-up" program that CEISMC received last year centered around manufacturing.
- Update website and MPRL safety training and test proposal forms through integration with the Institute for Materials.

APPENDIX A

List of Participating MPRL Faculty

S.D. Antolovich, School of Materials Science and Engineering/ME – Fatigue, deformation and degradation of materials, high-temperature behavior of materials, application of mechanics and materials to structural failures, and fracture mechanics.

A. Antoniou, G.W. Woodruff School of Mechanical Engineering - Micromechanics of deformation in cellular materials and metallic glasses, using both experimental measurements and numerical modeling; synthesis and mechanical behavior of nanostructured materials.

K. Gall, School of Materials Science and Engineering/ME - Development and characterization of advanced material systems for implementation into emerging technologies; experimental and computational studies emphasizing the mechanical behavior of materials at multiple length scales. Biomaterials and biomimetics.

H. Garmestani, School of Materials Science and Engineering - Quantitative characterization of materials, diffraction methods, statistical continuum mechanics treatments of heterogeneous materials; materials design.

A. Gokhale, School of Materials Science and Engineering - Quantitative microscopy, modeling of microstructures, quantitative relationships between microstructure and mechanical behavior of materials.

S. Graham, G.W. Woodruff School of Mechanical Engineering/MSE - Thermophysical property measurement at small scales; nanoscale heat transfer in materials and interfaces.

W.S. Johnson, School of Materials Science and Engineering/ME - Fatigue and fracture behavior of advanced materials, including nonlinear and temperature dependent behavior; development of life prediction methodologies.

K. Kalaitzidou, G.W. Woodruff School of Mechanical Engineering/MSE - Development and characterization of advanced polymer based particles or composites with superior properties for a wide range of applications.

S. Kalidindi, G.W. Woodruff School of Mechanical Engineering/MSE – Designing material internal structure for optimal properties and performance and identifying hybrid processing routes for its manufacture.

D.L. McDowell, G.W. Woodruff School of Mechanical Engineering/MSE - Cyclic viscoplasticity; microstructure-sensitive fatigue; multiscale modeling from atomistics to continuum; finite strain inelasticity, defect field mechanics; damage and deformation of metallic systems; materials design.

S. Melkote, G.W. Woodruff School of Mechanical Engineering - Characterization of the effects of machined surface integrity on fatigue life; constitutive models for high strain, strain rate and temperature processes.

C. Muhlstein, School of Materials Science and Engineering - Deformation, fatigue, fracture mechanics, degradation mechanisms, structural materials, composite materials, nanomaterials, thin films.

R.W. Neu, G.W. Woodruff School of Mechanical Engineering/MSE - Thermomechanical fatigue, environmental effects, fretting fatigue, creep, fatigue life prediction methods, mechanics of phase transformations, viscoplasticity.

O. Pierron, G.W. Woodruff School of Mechanical Engineering - Experimental and analytical characterization of fracture and fatigue of small scale materials (thin films, nanostructures), structural reliability of MEMS/NEMS devices, environmental effects.

P. Singh, School of Materials Science and Engineering – Environmental-induced damage and failure in structural alloys and composites, corrosion kinetics, stress corrosion cracking, high temperature oxidation.

S. Sitaraman, G.W. Woodruff School of Mechanical Engineering – Fabrication, characterization, thermo-mechanical predictive modeling and reliable design of micro-scale and nano-scale structures.

N. Thadhani, School of Materials Science and Engineering/ME - Materials aspects of dynamic deformation, including fracture and flow behavior of solid and porous materials, synthesis of intermetallics and ceramics materials utilizing effects of high-strain-rate loading.

S. Xia, G.W. Woodruff School of Mechanical Engineering - Experimental solid mechanics, nano and micromechanics, mechanics of energy storage and conversion materials, mechanics of heterogeneous media, fracture and fatigue of active materials.

M. Zhou, G.W. Woodruff School of Mechanical Engineering/MSE - High strain rate behavior of materials, experimental and computational studies of shear banding and deformation of heterogeneous materials; atomistic simulations of functional oxides and nanowires.

T. Zhu, G.W. Woodruff School of Mechanical Engineering/MSE - Atomistic modeling of defect nucleation in materials; transition states and defect kinetics; coupled multiphysics problems at nanoscales.

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* /ME denotes joint appointment in the Woodruff School of Mechanical Engineering
/MSE denotes joint appointment in the School of Materials Science and Engineering