

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

2011-2012 Annual Report

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Participating Units:
G.W. Woodruff School of Mechanical Engineering
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(also interfaces with AE, CEE, ECE, GTRI)

College of Engineering
Georgia Institute of Technology

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MPRL STATUS AND SUMMARY OF 2011-2012 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.
- 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 on Computational Materials Design).
- Characterization and quantitative analysis of microstructure and damage in engineering materials such as structural alloys, composites, metal foams, biomaterials and nanostructured materials and alloys.
- Durability and degradation of aging materials and structures.

Participating faculty (18) 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) and ¼ time Research Engineer J.D. Huggins. Mr. Brown principally serves the MPRL facilities located in Bunger-Henry and Love Buildings, and provides technical oversight and support for systems within the MaRC Hi-Bay. Mr. Huggins has been primarily responsible for the MaRC Hi-Bay MPRL, although his responsibilities have been broadened since September 2011 by virtue of extended medical leave(s) of Mr. Brown.

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

- Tensile and fatigue testing facilities
- Small scale testing laboratory
- High temperature testing (TMF)
- Drop weight impact tester
- Thermal aging and creep facilities
- Fretting test rig
- 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 the GT Institute for Electronics and Nanotechnology (IEN) and the Center for Nanostructure

Characterization and Fabrication (CNCF). 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, and mechanical behavior of materials. A graduate certificate in the Mechanical Properties of Solids 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, 2011 to June 30, 2012 are summarized in the Table below, with 15 of 18 MPRL faculty responding, 13 of whom stated that they had some level of research activity within the MPRL during the past year. It is noted that Professors Muhlstein (MSE) and Xia (ME) just joined this past academic year and are not included in these numbers.

# Faculty Reporting Funded Activity	Published Refereed Papers	# Funded Projects	Students Graduated		Faculty & Student Honors /Awards
			M.S.	Ph.D.	
13	84	42	4	13	6

Active MPRL faculty reported 128 conference presentations and seminars during this period. Approximately \$3.65M was expended in externally sponsored research during the past year on projects related to MPRL facilities or thrusts, for an average of approximately \$281K per each of the 13 MPRL faculty members who reported activity in the MPRL during this period. The distribution of per capita funding of the 13 faculty respondents this past year whom were actively involved in MPRL research was as follows: at or above \$300K (6), between \$200-299K (1), \$100-199K (3), \$1-99K (3). The PhD student production was the highest of any year in the past decade.

Highlights

Administrative highlights of 2011-2012 included the following:

- The Dean of CoE approved Rick Neu as MPRL Associate Director, given the pending retirement of longtime Associate Director Steve Johnson.
- Successfully installed and supported vital upgrades of two thermo-mechanical fatigue test controllers that are key to research within the Pratt & Whitney/GT CoE Center of Excellence.
- Successfully brought on research engineer J.D. Huggins in ME at 25% support level with support of the Dean’s office to provide bridge support in view of ongoing medical leave and phased retirement plans of Research Equipment Specialist Rick Brown.
- Working with ME, MSE and CoE to house laboratories of new hires C. Muhlstein (MSE) and S. Xia (ME), a work still in progress.

Research program highlights and development activities include:

- The Center for Computational Materials Design (CCMD), a NSF I/UCRC joint with Penn State, completed its 7th year in June 2012, and involves a substantial number of MPRL faculty (McDowell, PI/PD, Neu, Zhou, Gokhale, Garmestani, and Zhu). 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) completed its 5th 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).
- Associate Director Rick Neu received the ASTM International Award of Merit for contributions to fatigue and fracture standards in May 2012. Over the past five years, Dr. Neu has prepared a new standard guide on fretting fatigue testing, participated in a round robin on creep-fatigue testing, and provided feedback on the revision of the TMF test standard. All were based on work conducted in MPRL.

Plans for 2012-2013

- Work with the Dean's office as necessary in the coming year or two to address the issue of supporting J.D. Huggins as a part time support person mentored by R.C. Brown. This is a critical element of bridging MPRL support as Mr. Brown contemplates retirement at some point.
- Update website (personnel, facilities, etc.).
- Integrate laboratories and activities of Muhlstein, Xia, and new hire (Fall 2012) S. Kalidindi from Drexel into the MPRL and enhance cooperative spaces in the Bunger-Henry Building.

APPENDIX A

List of Participating MPRL Faculty

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 fractography and microscopy (stereology), 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 - Experiments and modeling of 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 - Development and characterization of advanced polymer based particles or composites with superior properties for a wide range of applications.

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 of hardened bearing steels; constitutive models for high strain, strain rate and temperature processes such as machining.

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, composite materials, fracture mechanics, creep, fatigue life prediction methods, mechanics of phase transformations.

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 - Thermo-mechanical modeling, reliability, and design of electronic packages.

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 - Atomistic modeling of defect nucleation in materials; transition states and defect kinetics; coupled multiphysics problems at nanoscales.

* /ME denotes joint appointment in the Woodruff School of Mechanical Engineering

/MSE denotes joint appointment in the School of Materials Science and Engineering