Materials Research Center at Missouri S&T

Bill Fahrenholtz
Missouri University of Science and Technology
billf@mst.edu
MRC History

• Started in 1964 by Prof. Bill James and Dean Ted Planje
• Building completed 1967, renovated 2011-2012
  – Renovation funded by campus ($2.2M) and NSF ($1.8M)
  – Renamed Straumanis-James Hall (SJH) in 2011
• Core funded center, evaluated based on return on investment
• Annually >$7M shared credit expenditures
• ~70 faculty, ~90 grad students, ~5000 samples run, ~20 external users
  – Majority of campus patents and royalty income
• Maintains materials analytical equipment (AMCL)
  – Housed in SJH and McNutt Hall; ~$10M equipment inventory
• Sr Investigators: 10 senior faculty with distinguished records as internal advisory panel
MRC Mission

• Enable the success of materials research and graduate education
  – Acquire and manage major research instrumentation
  – Facilitate collaborative proposals and projects
  – Advocate for materials research on campus and off

• Major resources
  – Straumanis-James Hall
  – Technical and administrative staff
  – Senior investigators and research investigators
  – Equipment
Straumanis-James Hall
# Research Investigators

**Chemistry**
- Dr. Amitava Choudhury
- Dr. William James
- Dr. Garry Grubbs
- Dr. Vadym Mochalin
- Dr. Manashi Nath
- Dr. Tom Schuman
- Dr. Lia Sotiriou-Leventis
- Dr. Risheng Wang
- Dr. Jeff Winiarz

**Chemical & Biochemical Engr**
- Dr. Sutapa Barua
- Dr. Douglas Ludlow
- Dr. Monday Okoronkwo
- Dr. Fateme Rezaei
- Dr. Ali Rownaghi

**Civil & Architectural Engr**
- Dr. Mohamed Elgawady
- Dr. Hongyan Ma
- Dr. John Myers
- Dr. Guney Olgun
- Dr. Chenglin Wu

**Chemistry**
- Dr. Ian Ferguson
- Dr. Jie Huang
- Dr. Chulsoon Hwang
- Dr. Chang-Soo Kim
- Dr. Dong-Hyun Kim

**Geosciences, Geological and Petroleum Engr**
- Dr. Baojun Bai
- Dr. David Borrok
- Dr. Abdulmohsin Imqam
- Dr. Marek Lcmealis
- Dr. Mingzhen Wei
- Dr. Wan Yang

**Materials Science & Engr**
- Dr. Delbert Day
- Dr. Fatih Dogan
- Dr. Aditya Kumar
- Dr. Simon Lekakh
- Dr. David Lipke
- Dr. Scott Miller
- Dr. Michael Moats

**Electrical & Computer Engr**
- Dr. Joseph Newkirk
- Dr. Matt O’Keefe
- Dr. Darrell Ownby
- Dr. Jeffrey Smith
- Dr. Jeremy Watts
- Dr. Haiming Wen

**Mechanical & Aerospace Engr**
- Dr. Douglas Bristow
- Dr. Jie Gao
- Dr. Frank Liou
- Dr. Heng Pan
- Dr. Jonghyun Park

**Mining & Nuclear Engr**
- Dr. Lana Alagha
- Dr. Carlos Castano
- Dr. Grzegorz Galecki
- Dr. Joseph Graham
- Dr. Josh Schlegel
- Dr. Guang Xu

**Physics**
- Dr. Aleksandr Chernatynskiy
Materials Research Center (MRC) and Advanced Materials Characterization Laboratory (AMCL)

**Director of MRC**
Dr. Bill Fahrenholtz (billf@mst.edu)

**Director of AMCL**
Dr. F. Scott Miller (smiller@mst.edu)

### Materials Research Center FY 19 Research Numbers
- **Number of Faculty**: 70+
- **Number of Students**: 75+
- **Research Expenditures**: ~$7,000,000

### MRC Research Areas
- Advanced Structural Ceramics
- Corrosion and Coatings
- Electrodeposition/Photocatalysis
- Sensors and MEMS Devices
- Glass
- Integrated Computational Materials Engineering (ICME)
- Steels and Metallic Alloys (Peaslee Steel Center)
- Electromagnetic Compatibility (EMC Lab at Hypoint)
- Primary Metals Production

### Research Areas
- **Electron Beam Lithography**
  - Raith eLINE Plus
    - Ultra-high resolution patterning (sub-5 nm lines in resist, sub-7 nm lines using e-beam deposition)
    - Four nanomanipulators for in-situ nanoprobing and nanoplotomtry
    - Gas injection system for deposition, etching or 3D nanosculpturing

### Scanning Electron Microscopy
- Helios NanoLab 600 FIB-SEM
  - 1.0 nm electron resolution
  - 5.0 nm ion beam resolution

### Transmission Electron Microscopy
- Tecnai F20 STEM
  - 0.24 nm TEM point resolution
  - 0.19 nm STEM resolution

### Atomic Force Microscopy
- Nanoscope IIIA
  - Atomic force microscope (AFM)
  - Reconstructs images
  - Sub-nanometer increments

### X-ray Photoelectron Spectroscopy
- Kratos Axis 165 XPS
  - Surface Chemistry and Depth Profiling
  - Elemental & Binding Energy Identification

### X-ray Diffraction
- PANalytical X'Pert Multipurpose Diffractometer
  - Temperatures up to 1600°C
  - 15 sample changer

### X-ray Fluorescence
- Oxford Instruments X-Supreme 8000
  - Benchtop instrument suitable for a wide variety of sample types
  - Covers elements Na to U

### Thermal Analysis
- TA Instruments SDT Q600
  - Measurement of Tg, specific heat, phase changes
  - Simultaneous TGA/DSC
  - Temperatures up to 1600°C
  - Transition temperatures and exothermic/endothermic reaction processes

### Electron Beam Lithography
- Raith eLINE Plus
  - Ultra-high resolution patterning (sub-5 nm lines in resist, sub-7 nm lines using e-beam deposition)
  - Four nanomanipulators for in-situ nanoprobing and nanoplotomtry
  - Gas injection system for deposition, etching or 3D nanosculpturing

### Electron Beam Lithography
- PANalytical X'Pert Materials Research Diffractometer
  - Thin Film Diffraction
  - Texture Analysis

### X-ray Fluorescence
- Oxford Instruments X-Supreme 8000
  - Benchtop instrument suitable for a wide variety of sample types
  - Covers elements Na to U

### Thermal Analysis
- TA Instruments SDT Q600
  - Measurement of Tg, specific heat, phase changes
  - Simultaneous TGA/DSC
  - Temperatures up to 1600°C
  - Transition temperatures and exothermic/endothermic reaction processes
FIB/SEM and TEM (Open position)

B-18 McNutt,

EBSD texture analysis of AM-fabricated aluminum
Dr. Leu, ISC & Dept. of ME

TEM and APT sample preparation

Micro-slotting technique for stress measurement
Dr. Newkirk, Dept. of MSE

High T corrosion of steel automotive components
Dr. Lekakh, PSMRC & Dept. of MSE; Ford Corp.; ORNL
Raith eLINE Plus (Dr. Clarissa Wisner)

**Electron beam lithography** (EBL or e-beam lithography) technique used to create the smallest features (~5 nm). A tightly focused beam of electrons exposes a pattern in a resist. The resist can then be developed. Pattern transfer can be completed either by etching and resist removal or evaporating a metal onto the resist and dissolving the remaining unwanted metal and resist.

- **Ultra-high resolution patterning** (sub-5 nm lines in resist, sub-7 nm lines using e-beam deposition)

- **Gas injection system** for deposition, etching or 3D nanosculpturing

- **Four nanomanipulators** for in-situ nanoprobing and nanoprofilometry

Precise manipulation of EBID nanostructures
A. Linden, Raith inhouse

Clarissa Wisner
B-18 McNutt
cvierret@mst.edu
XPS and XRF (Brian Porter)

- ThermoFisher NEXSA
  - Surface chemistry and depth profiling
  - Detection Li to U
  - Up to 8 nm penetration depth
  - In-situ Raman spectrometer
  - Being installed this week

- Oxford X-Supreme 8000 XRF
  - Benchtop instrument suitable for a variety of sample types
  - Detection from Na to U
  - Up to 10 µm penetration depth
  - Can be operated by researchers

Brian Porter, G4 SJH, porterbj@mst.edu
Everything Else (Dr. Eric Bohannan)

• PANalytical MRD XRD
  – Thin film, pole figures, X-ray reflectivity, etcetera

• PANalytical MPD XRD
  – 15 sample changer available
  – SAXS attachment
  – Up to 1500°C reliably

• TA DSC 2010
  – From liquid N$_2$ to 600°C
  – Ramp up only, no controlled cool

• TA Q600 SDT
  – Simultaneous DSC/TGA
  – Up to 1500°C

Eric Bohannan, G6 SJH, bohannan@mst.edu
Everything Else (Dr. Eric Bohannan)

• Hirox KH-8700 3D Digital Optical Microscope
  – Surface roughness and imaging for non-transparent/reflective samples
  – Bring a flash drive; not networked

• DI Scanning Probe Microscope
  – AFM mode is fully functional
  – Surface roughness and texture
  – Modulus
  – STM mode is not working

• Hitachi TM-1000 Tabletop Scanning Electron Microscope
  – 20-10,000X
  – Sample sizes up to 70mm in diameter and 20mm thickness
  – No EDS

Eric Bohannan, G6 SJH, bohannan@mst.edu
Other New Instruments

- PRISMA-E Color SEM
  - Variable pressure SEM
  - High/low vac modes
  - EDS, EBSD, and WDS
  - Continuous EDS analysis to highlight compositional differences during imaging

- Helios Hydra CX
  - Dual beam focused ion beam SEM
  - Sputtering with Ar, N, O, or N ions
  - Eliminates Ga contamination
  - Improved automation for TEM specimen preparation
Strategic Plan

- MRC focuses enabling the success of materials researchers
  - Utilize center resources to support research
    - SJH office and laboratory space
    - MRC staff (administrative and technical)
    - AMCL equipment
    - Senior investigators and research investigators
      - Provide access to characterization equipment
        - Expert staff, training, and maintenance
  - Increase research activity
    - Enable research through availability of resources
    - Promote teaming and application for major grants
    - Provide seed funding for early-career faculty
MRC Affiliations

- Any students, staff, or faculty can use MRC resources for research purposes
- Senior investigators (SI); about 10
  - Internal advisory committee, senior faculty active in materials research
  - Nominations and selection as needed
  - Base E&E funding from MRC budget (1:1 matching required)
  - Returned F&A for research support expenses (1:1 matching required)
- Research investigators (RI);
  - Investigators with >$10K/yr in shared credit research expenditures
  - Same benefits as Investigators plus returned F&A for research support expenses (1:1 matching required)
- Investigators (I);
  - Any faculty interested in using MRC resources
  - $500 for use of AMCL equipment (1:1 matching required)
  - An additional $500 for untenured faculty (no matching required)
Questions?

• Any questions about MRC can be directed to billf@mst.edu