

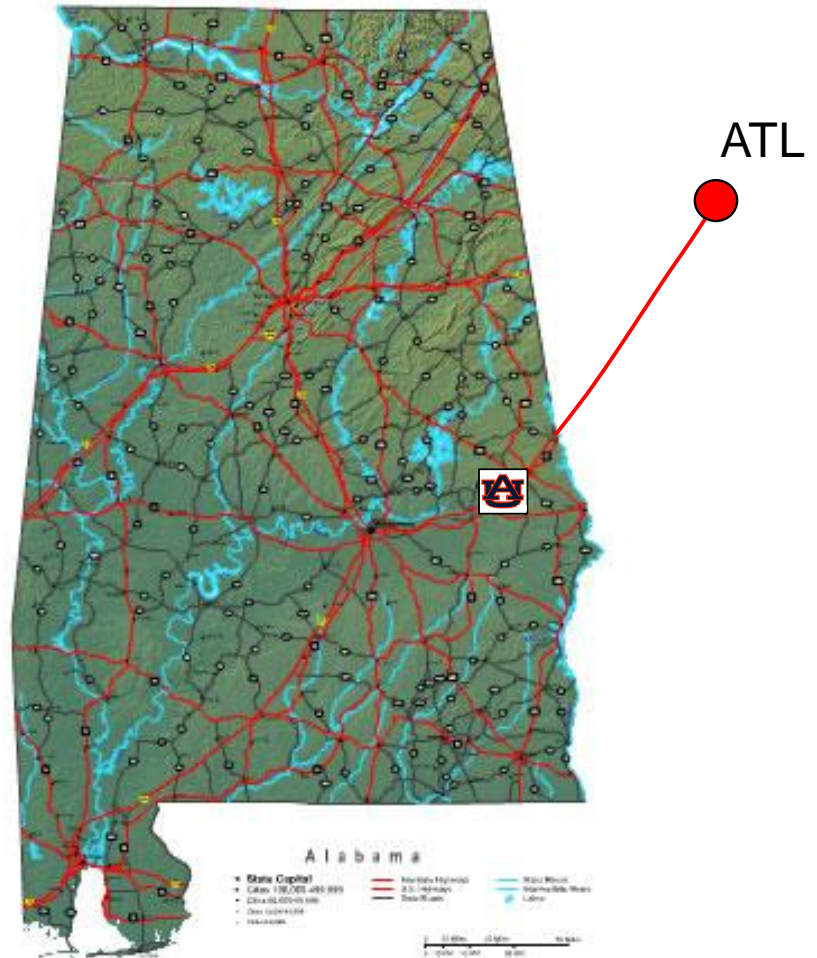
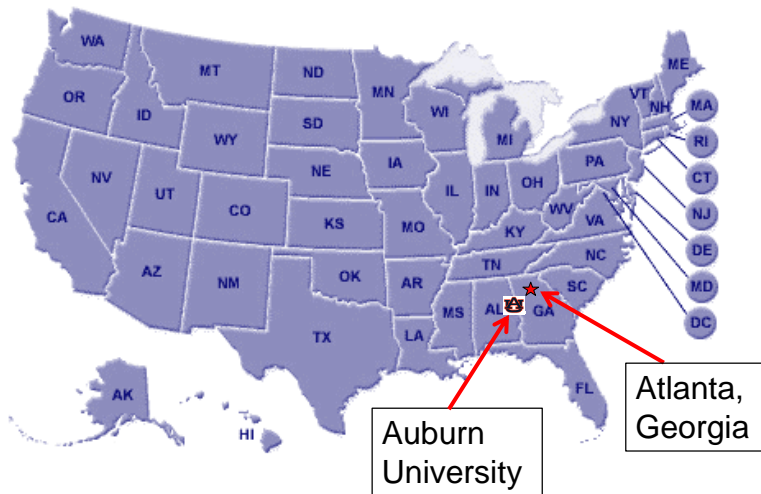
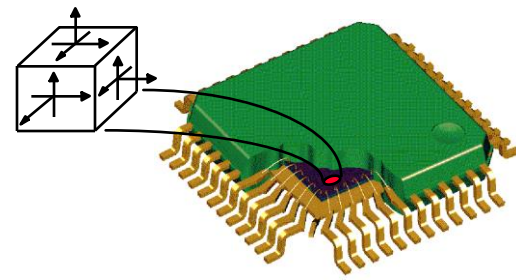
OVERVIEW OF THE DEPARTMENT OF MECHANICAL ENGINEERING AT AUBURN UNIVERSITY

Jeffrey C. Suhling
Quina Professor and Department Chair
Department of Mechanical Engineering
Auburn University

SAE FD&E Committee
October 11, 2018

AUBURN UNIVERSITY

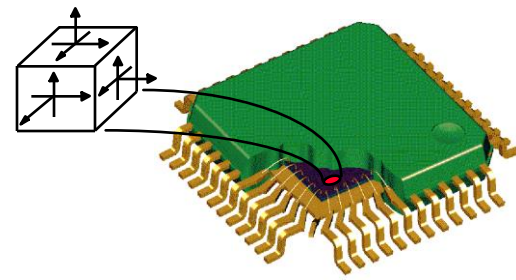
Auburn, Alabama, USA



30,000 Students

AUBURN UNIVERSITY

Auburn, Alabama, USA

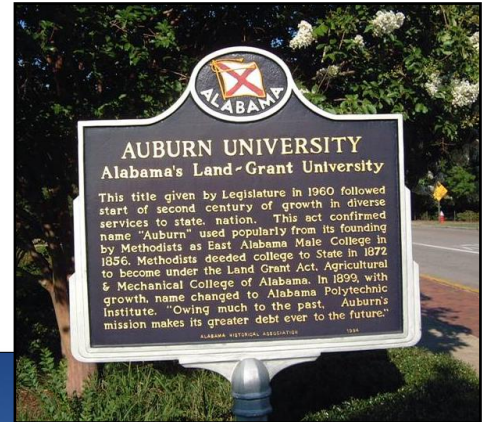


Auburn University

- Formed in 1856
- Land-grant institution
- College of Engineering established in 1872
- 30,800 total students
- 140 degrees
- 13 different colleges

Auburn/Opelika Area

- Population ~160,000
- 90 minutes from Atlanta Airport
- 1 hour from Montgomery
- Great year-round weather



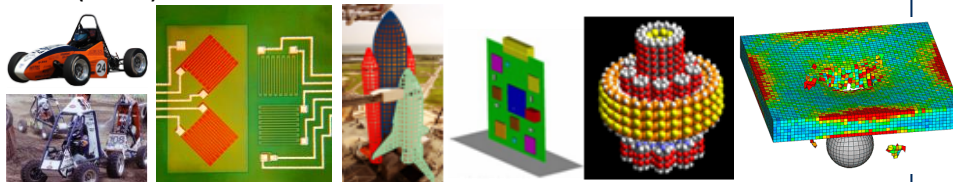


● ABOUT US

- Two Academic Programs: **Mechanical Engineering** and **Materials Engineering**
- 41 Full Time Faculty
- 1400 Undergraduate Students (Fall 2018)
- 220 Graduate Students (Fall 2018)
- 260 Undergraduate Degrees (2017-18)
- 70 Graduate Degrees (2017-18): 58 MS, 12 PhD
- \$8M Annual Research Funding (2016-17)
- Ranked in Top 25 ME Programs by Funding Level
- 287 Publications (2017): 10 Books, 98 Journal Articles, 179 Conference Papers

● PROGRAM HIGHLIGHTS

- Rigorous Curricula, Hard Working and Talented Students (Incoming Student Average ACT was 29.5, Fall 2018)
- Nationally Competitive Undergraduate Student Design Teams (Baja SAE, Formula SAE, Lunar Rover, Hyperloop, etc.)
- Successful Alumni, Annual Alumni Conference
- Excellence in Scholarship: Research, Graduate Education, Publications: Books, Chapters, Journal and Conference Articles, Extremely Active in Professional Societies and Activities
- National Recognized Outreach Efforts: LITEE, GOP, AETAP
- Excellent Facilities: Wiggins Hall (2012), Woltosz Engineering Research Laboratories (2012), Wilmore Hall (2004), Gavin Labs (2018)



● OUR RESEARCH INTERESTS

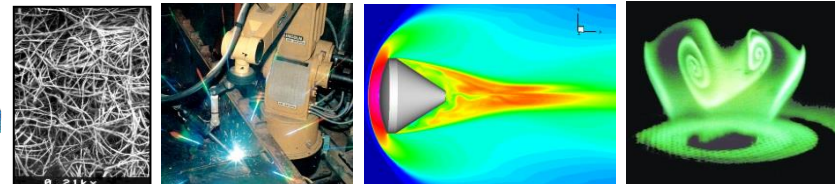
- **Materials** (Sensors, Bio/Nano, Detection and Food Safety, Air Quality)
- **Electronic Packaging** (Electronics Reliability in Harsh Environments, MEMS, Electronics Cooling)
- **Vehicle Technology** (Unmanned/Autonomous; Dynamics, Stability, and Controls; Advanced Powertrains: Fuel Cell and Hybrid)
- **Additive Manufacturing**
- **Energy Systems**
- **Biomechanics**
- **Flexible Hybrid Microelectronics**



● OUR UNIQUE CAPABILITIES

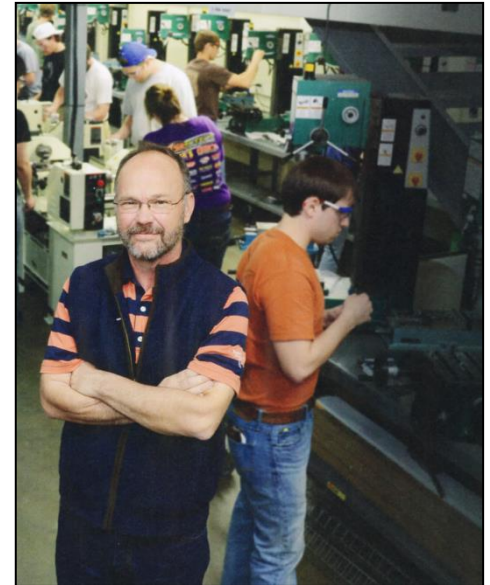
Research Centers

- **AUDFS** (Auburn University Detection and Food Safety Center, AU Peak of Excellence, USDA)
- **NCAME** (National Center for Additive Manufacturing Excellence, NASA/ASTM/NIST)
- **CAVE³** (NSF Center for Advanced Vehicle and Extreme Environment Electronics)



PROGRAM SPOTLIGHT

Design and Manufacturing Laboratory



ME

Department of Mechanical Engineering



PROGRAM SPOTLIGHT

War Eagle Motorsports



2018
16th in Michigan
7th in Nebraska



Three Teams in 2018

1. Combustion
2. Electric
3. Autonomous

ME

Department of Mechanical Engineering



FACULTY

Department of Mechanical Engineering



Abdel-Hadi



Adanur



Ayasoufi



Beale



Beidaghi



Bevly



Bhavnani



Burch



Chen



Cheng



Chin



Choe



Cremaschi



Crocker



Davis



Dyer



Fergus



Flowers



Gowayed



Harris



Hoffman



Jackson



Jones



Khodadadi



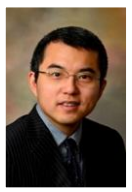
Kim



Knight



Lall



Lou



Mackowski



Madsen



Marghitu



Martin



Mishra



Overfelt



Payton



Perkins



Prorok



Ragan



Raju



Roberts



Schwartz



Shamsaei



Simonian



Sinha



Suhling



Thakur



Thompson



Tippur



Tsolas



Williams



Zabala



Zee

ME

Department of Mechanical Engineering



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RESEARCH AREAS

AU Mechanical Engineering



ME

Department of Mechanical Engineering

RESEARCH AREAS

AU Mechanical Engineering

- Acoustics
- Additive Manufacturing
- Advanced Powertrains
- Automotive Design
- Biohazard Detection
- Biomechanics
- Casting
- CFD
- Coatings and Thin Films
- Combustion
- Composite Materials
- Design of Machinery
- Dynamic Stability
- Electrical Connectors
- Electronics Cooling
- Electronic Packaging
- Electro-Optics
- Energy Harvesting Devices
- Energy Storage Devices
- Energy Systems
- Experimental Mechanics
- Finite Element Analysis
- Fluid Mechanics
- Flywheels
- Food Safety
- Fracture Mechanics
- Fuel Cells
- Gas Turbines
- GPS Guidance and Control
- Graded Materials
- Heat Pipes
- Heat Transfer
- HVAC
- Impact Dynamics
- Interferometry
- Magnetic Bearings
- Materials Processing
- MEMS
- Microfluidics/Nanofluidics
- Microscopy
- Motion Analysis
- Nanotechnology
- NDT/NDE
- Noise Control
- Nonlinear Optics
- Nonlinear Systems
- Optical Metrology
- Organic Semiconductors
- Prognostics (PHM)
- Radiation
- Robotic Welding
- Robotics
- Rotor Dynamics
- Sensors (Biological)
- Sensors (Chemical)
- Sensors (Magnetostriptive)
- Sensors (MEMS)
- Sensors (Piezoelectric)
- Sensors (Piezoresistive)
- Smart Materials
- Solar Energy
- Sound and Vibration
- Test Chips
- Thermal Systems
- Tribology
- Unmanned Vehicles (UAV)
- Vehicle Stability Control

RESEARCH AREAS

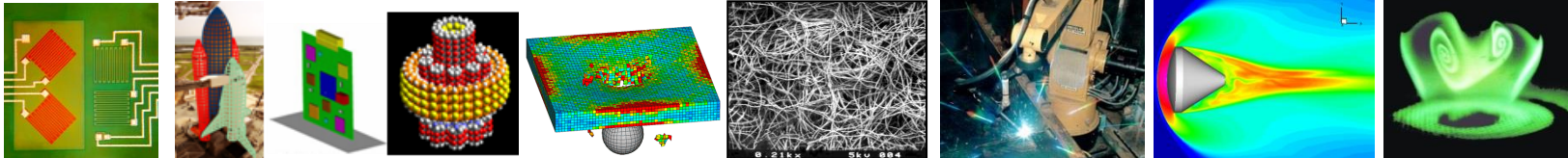
AU Mechanical Engineering

- Research Thrusts

- **Materials** (Sensors, Bio/Nano, Detection and Food Safety)
- **Electronic Packaging** (Reliability in Harsh Environments)
- **Vehicle Technology** (Unmanned/Autonomous; Dynamics, Stability, and Controls; Advanced Powertrains: Fuel Cell and Hybrids)
- **Additive Manufacturing** (Metals, Fatigue and Process Control)
- **Energy Systems** (Energy Efficient Building Energy Systems)

- Research Centers

- MREC (Materials Research and Education Center)
- AUDFS (Auburn University Detection and Food Safety Center)
- CPAC (Center for Polymers and Advanced Composites)
- CAVE³ (Center for Advanced Vehicle and Extreme Environment Electronics)
- NCAME (National Center for Additive Manufacturing Excellence)



ME

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RESEARCH SPOTLIGHT

Research on Autonomous Vehicles and Vehicle Dynamics/Control

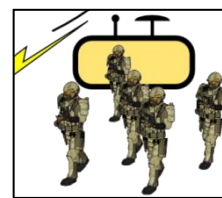
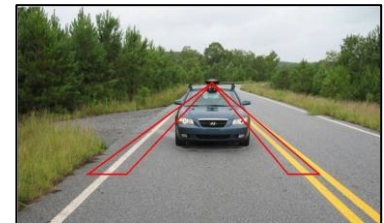
David Bevly, PI

\$15M Research over Past 10 Years

Currently 26 Students (8 PhD, 14 MS, 4 BS)

Example Research Topics

- Unmanned Autonomous Vehicles
- Vehicle modeling
- Determination of rollover propensity
- Vehicle sensor fusion/integration
- GPS/INS navigation
- IMU & laser scanner fusion
- Sensor characterization and modeling
- Development of a software GPS receiver
- High speed control of ground vehicles



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RESEARCH SPOTLIGHT

Research on Autonomous Vehicles and Vehicle Dynamics/Control

Autonomous Vehicle Development
Vehicle Sensor Fusion/Integration



Sensor Characterization and Modeling



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Department of Mechanical Engineering

GPS/INS Navigation



IMU & Laser Scanner Fusion



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RESEARCH SPOTLIGHT

Research on Autonomous Vehicles and Vehicle Dynamics/Control

DARPA Grand Challenge



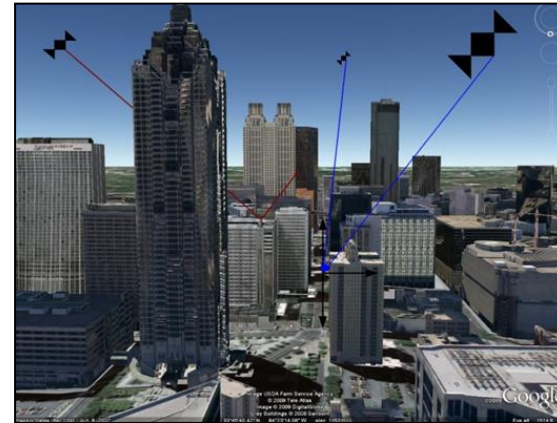
High Speed Control of Ground Vehicles



Vehicle Platooning



GPS/INS Navigation and Control



ME

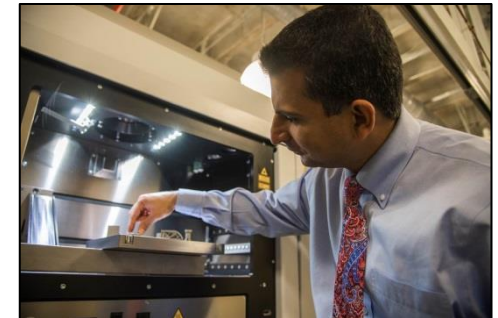
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RESEARCH SPOTLIGHT

Additive Manufacturing



ME

Department of Mechanical Engineering

RESEARCH SPOTLIGHT

NCAME - Additive Manufacturing (Metals)



NCAME (National Center for Additive Manufacturing Excellence)



RESEARCH SPOTLIGHT

NCAME Partners - Additive Manufacturing (Metals)

■ = Industry	■ = Academia	■ = Government	■ = Non-Profit Organization
■ Aerojet Rocketdyne		■ NASA	
■ Alabama Automotive Manufacturers Assoc. (AAMA)		■ NAVAIR	
■ AlphaSTAR		■ National Center for Adv. Manufacturing (NCAM)	
■ AmericaMakes		■ NIST	
■ BioHorizons		■ Pinnacle X-Ray Solutions	
■ Boeing		■ Plasma Processes	
■ Delta Air Lines		■ Polytechnic University of Milan (Italy)	
■ EOS North America		■ Renishaw (U.K.)	
■ Fiat-Chrysler Automobiles		■ Quintus Technologies	
■ FIT Center for Adv. Manuf. & Innovative Design (CAMID)		■ SLM Solutions	
■ GE Additive		■ Smith & Nephew	
■ GE Aviation		■ Society of Manufacturing Engineers (SME)	
■ GE Aviation (Auburn, AL Production Facility)		■ Southern Research	
■ Geocent		■ Southwest Research Institute	
■ Governor of Alabama		■ Surface Dynamics	
■ HBM nCode (Germany & U.S.)		■ Toyota	
■ Imperial College London (U.K.)		■ TRUMPF (Germany)	
■ KITECH (South Korea)		■ University of Mississippi Medical Center (UMMC)	
■ Lockheed Martin		■ University of Alabama - Tuscaloosa	
■ LPW		■ University of Memphis	
■ Medtronic		■ Victory Solutions	
■ MicroPort Orthopedics		■ Viwa (Mexico)	
■ Missouri Research Reactor Center (MURR)		■ Wright Medical	

RESEARCH SPOTLIGHT

AU Initial Investments - Additive Manufacturing

- **Teaching equipment: ~\$1M**
 - Multiple polymer-based 3D printers
- **Research equipment: ~\$7+M**
 - EOS M290
 - Renishaw AM 250
 - Concept Laser MLAB 100R
 - CNC-based wire deposition
 - Powder characterization
 - Fatigue testing laboratory
 - Microscopy center



ME

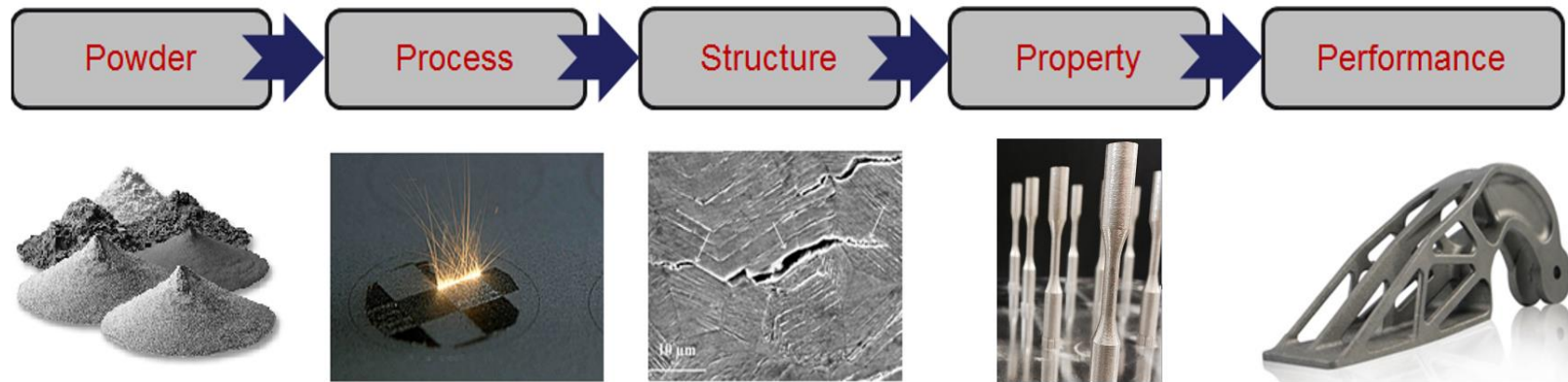
Department of Mechanical Engineering



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RESEARCH SPOTLIGHT

Additive Manufacturing (Metals)

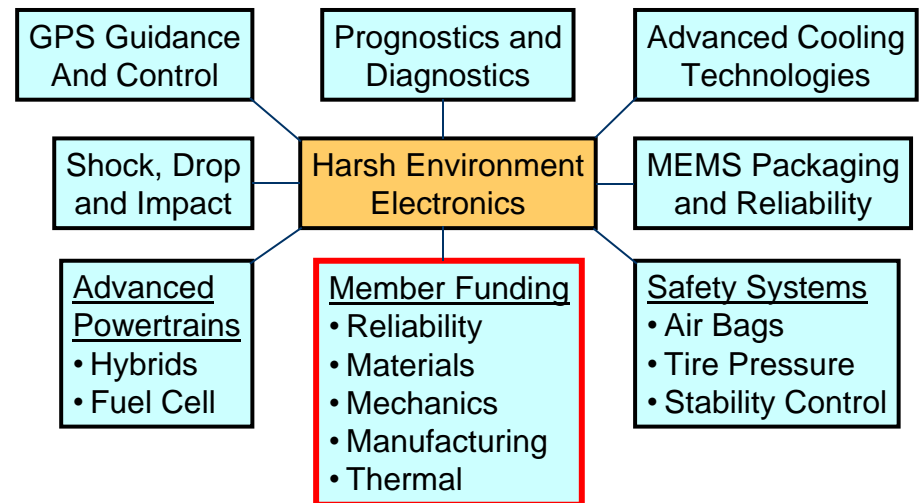


- Perform industry-driven research & standards development.
 - Better understand AM powder-process-structure-property-performance relationships.
 - Use Auburn and other collaborator resources to achieve excellence.
- Rolling, up-to-date gap analyses (must adjust with trends).
- Work with ASTM International Technical Committees.
 - ASTM Executive Committee F42.09 on Additive Manufacturing Technologies
 - F04, E08, E07, E10, B09, ...

RESEARCH SPOTLIGHT

CAVE³ - Center for Advanced Vehicle & Extreme Environment Electronics

- A National Science Foundation Industry/University Cooperative Research Center (I/UCRC)
- Objective: Research and Development (in Collaboration with Industry) on Electronic Packaging in Harsh Environments
- Demographics:
 - 20 Member Companies
 - 15 Faculty, 5 Staff
 - 35 Graduate Students
 - 10 Laboratories

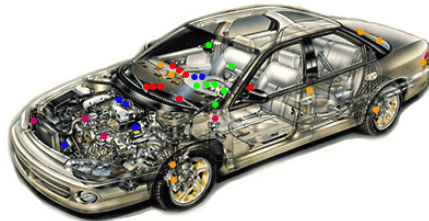


Director: Pradeep Lall
E-mail: lallpra@auburn.edu

RESEARCH SPOTLIGHT

CAVE³ - Center for Advanced Vehicle & Extreme Environment Electronics

Center for Advanced Vehicle and Extreme Environment Electronics (CAVE3)



ME

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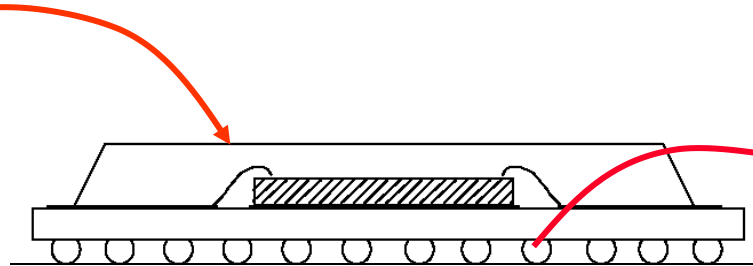
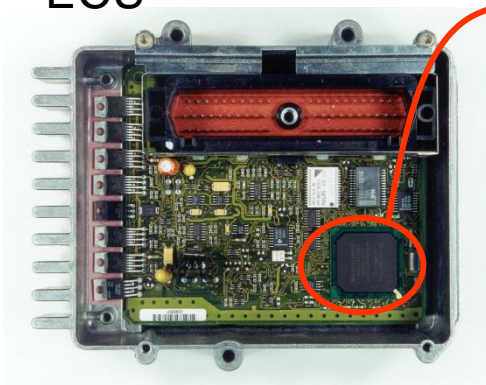


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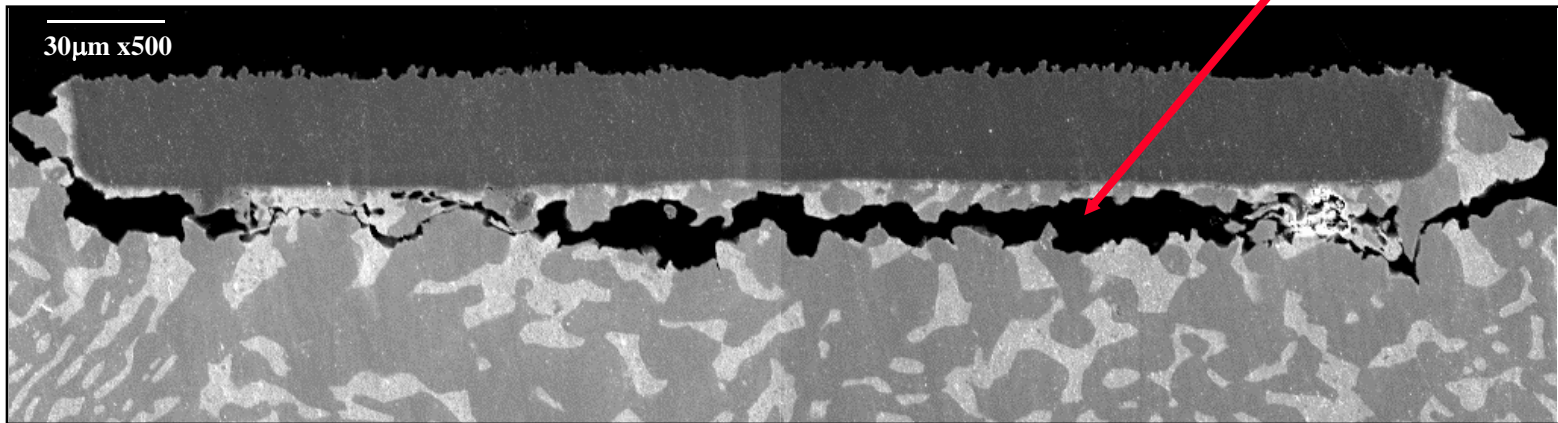
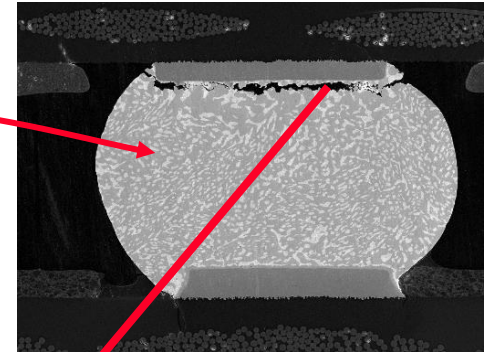
VEHICLE MODULE

Example Failure Mode

ECU



Solder Joint Fatigue
(Ball Grid Array)



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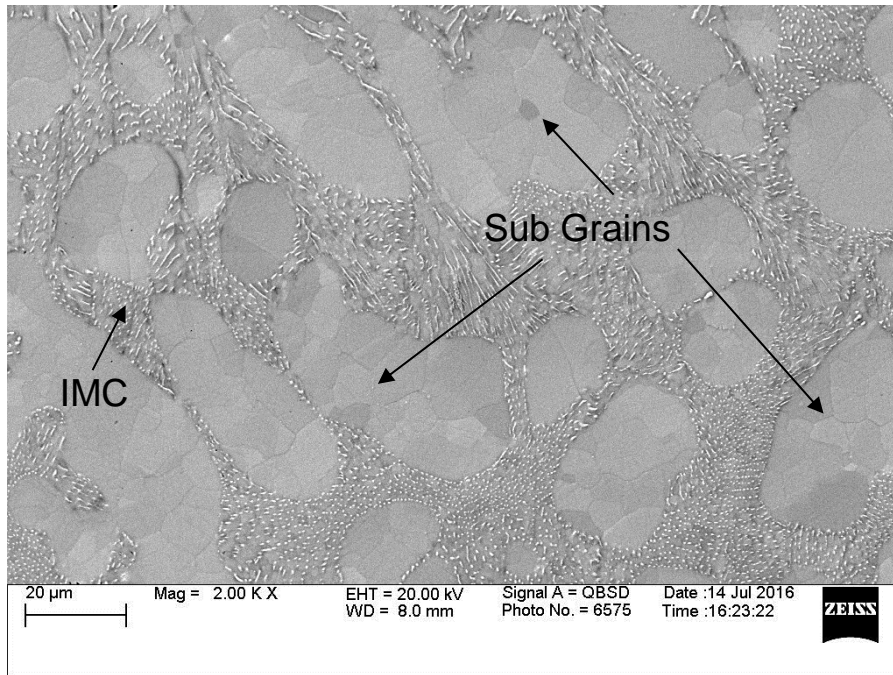
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AGING EFFECTS

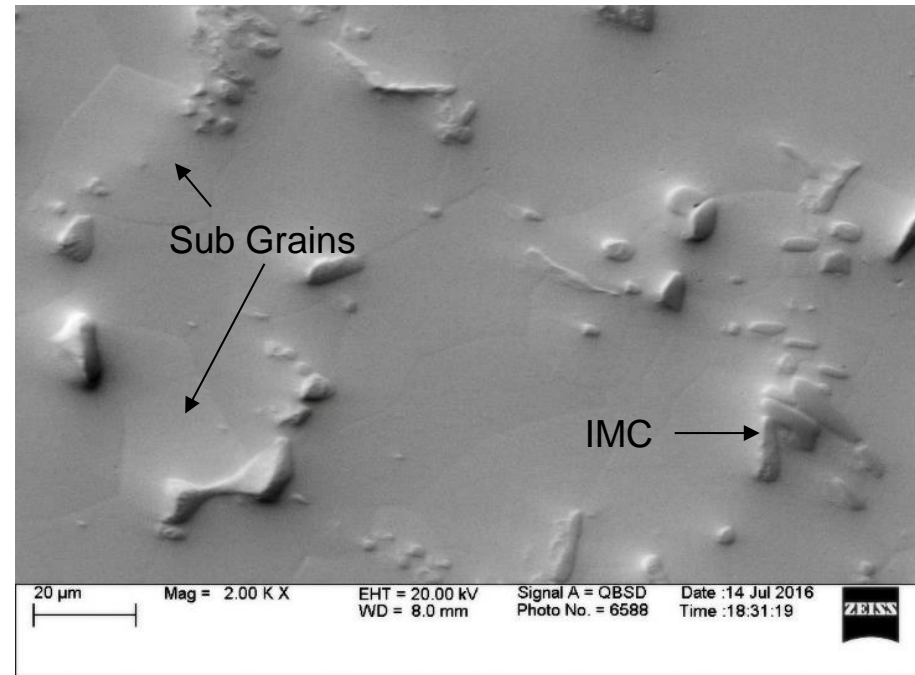
Microstructure Evolution

SAC305, Aging at 125 °C

IMCs: Ag_3Sn , Cu_6Sn_5



SAC305 (RF, Before Aging, 2000X)

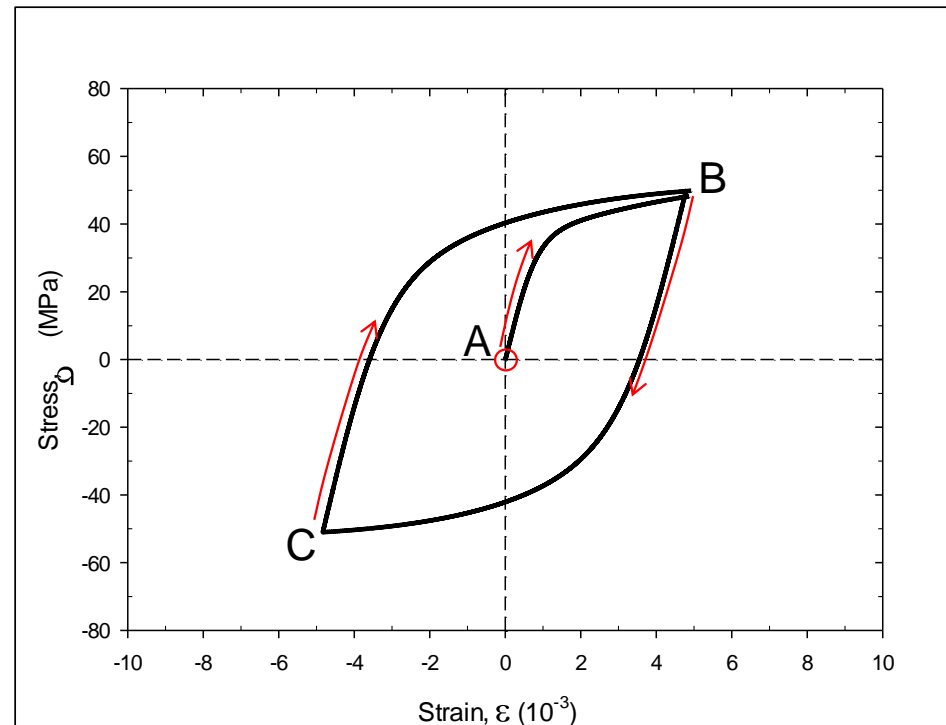
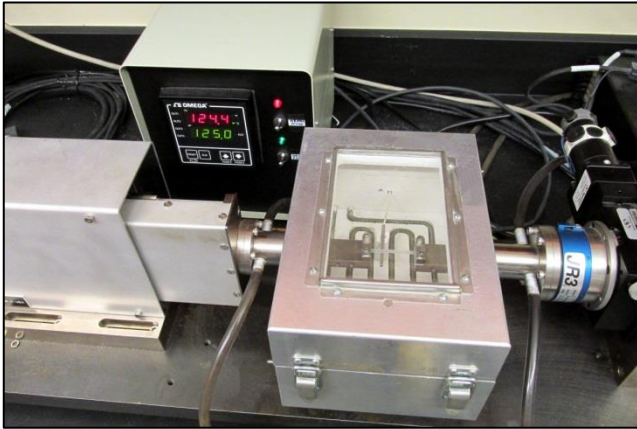


SAC305 (RF, After Aging, 2000X)

Aging Leads to Coarsening of IMC Particles, Increase in Subgrain Size, and Weakening of Dendrite Structure

CYCLIC STRESS-STRAIN

Hysteresis Loops Developed During Repeated Cycling

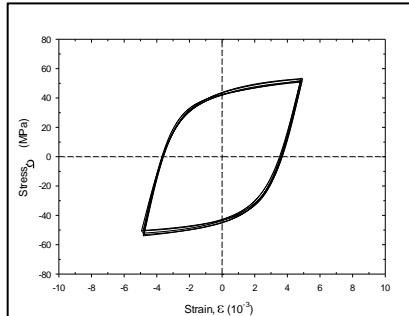


cave³

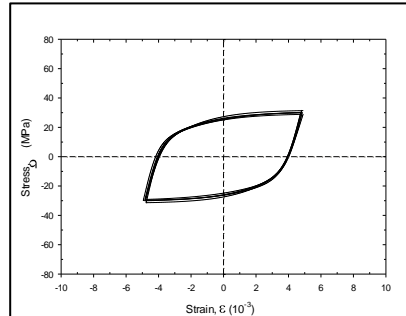
NSF Center for Advanced Vehicle and Extreme Environment Electronics

TEST RESULTS

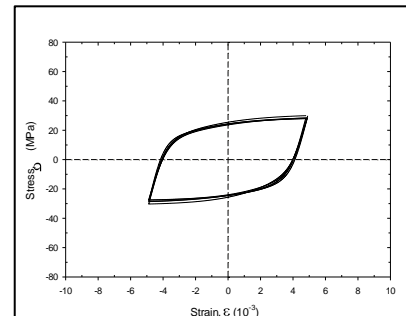
SAC305 (WQ)



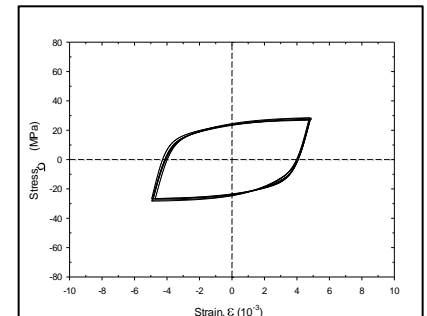
(a) No Aging



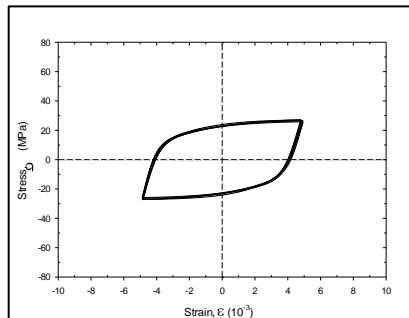
(b) 5 Days of Aging



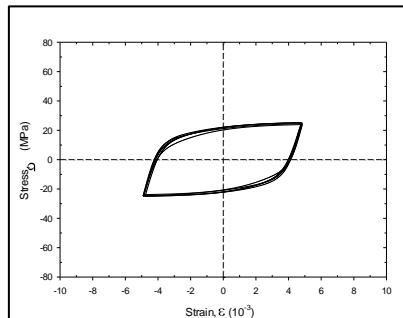
(c) 10 Days of Aging



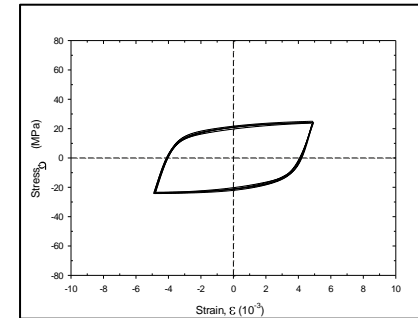
(d) 20 Days of Aging



(e) 30 Days of Aging



(f) 60 Days of Aging

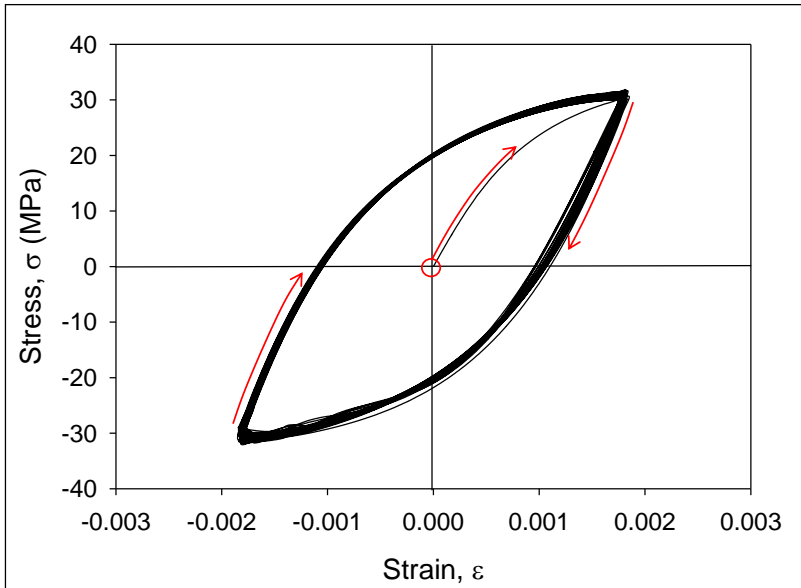


(g) 150 Days of Aging

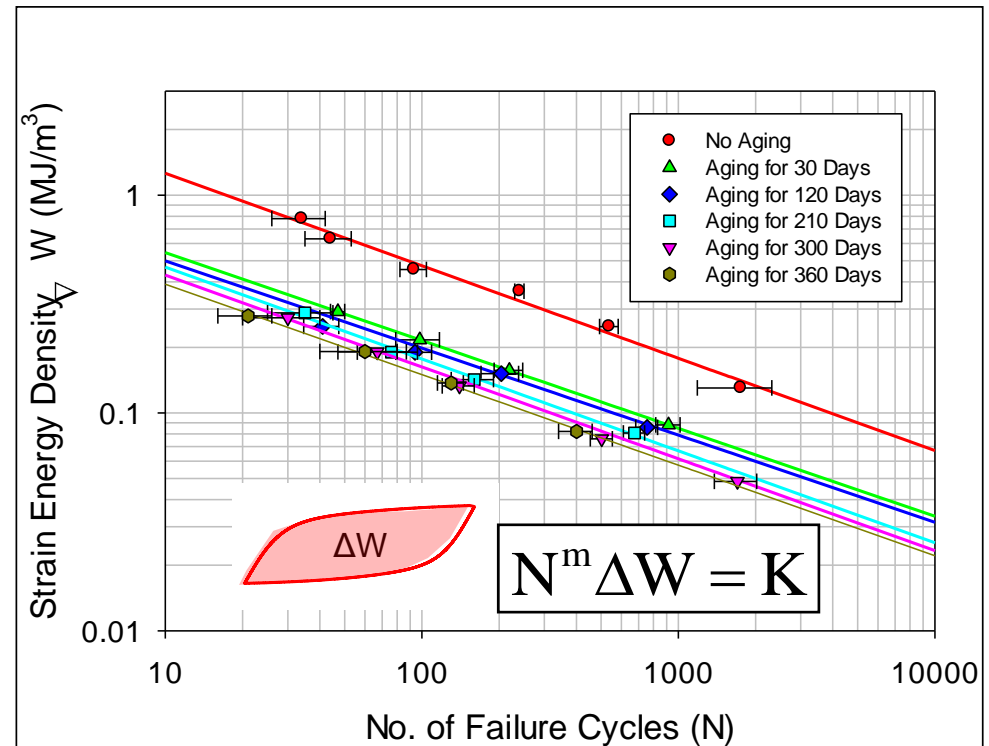
CYCLIC STRESS-STRAIN

Hysteresis Loops and Fatigue Curves

SAC405

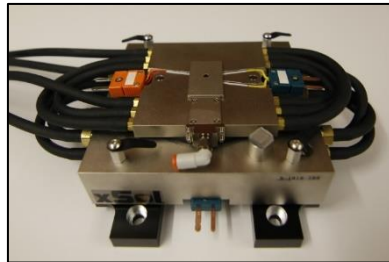
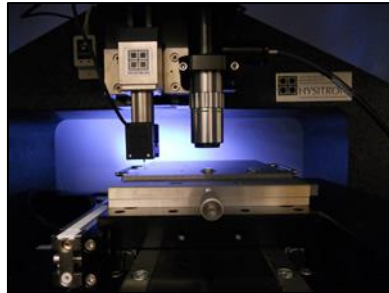


Aging Effects (Solder)

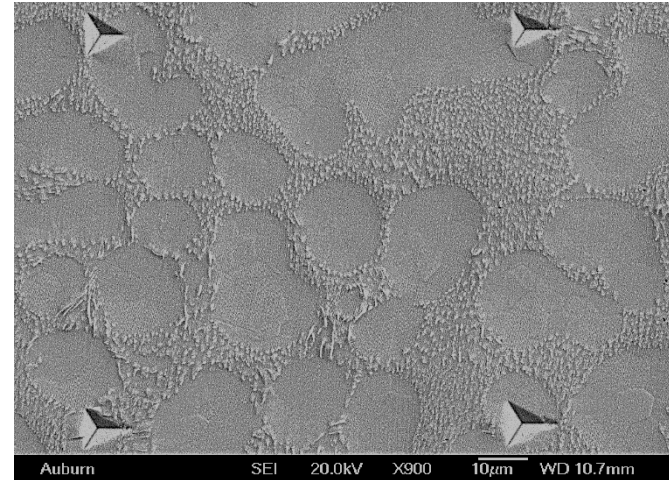
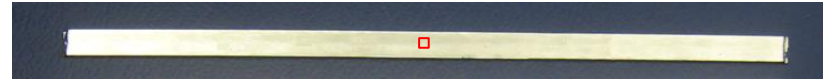


EXPERIMENTS

Microstructural Evolution



Hysitron TI 950 (SPM)



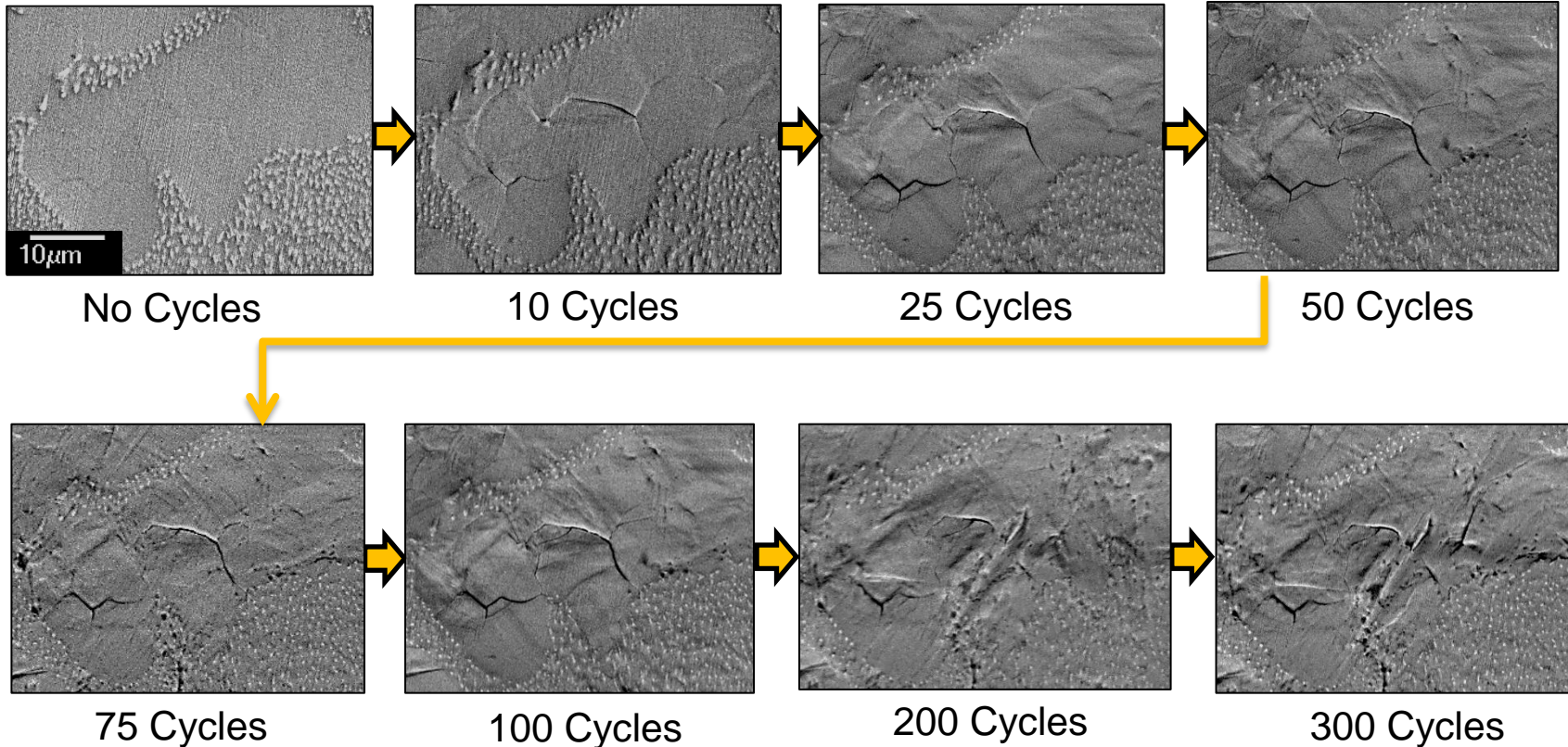
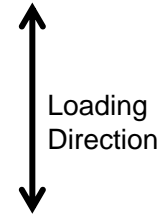
A Typical Fixed Region with Indentation Marks



SEM (JEOL JSM-7000F)

EFFECTS OF CYCLING

Microstructural Evolution (SAC305)





THIS IS DEDICATION.

THIS IS CREATIVITY.

THIS IS INSPIRING.

THIS IS ENGINEERING EDUCATION.

THIS IS AUBURN.