CORROSION ENGINEERING AT NCERCAMP

The University of Akron

The National Center for
Education and Research on Corrosion
and Materials Performance

NCERCAMP

AT THE UNIVERSITY OF AKRON

Corrosion and materials degradation costs the United States $276 billion annually, according to "Corrosion Costs and Preventive Strategies in the United States," a study released by NACE International and the U.S. Federal Highway Administration. With those costs continually rising, UA recognizes a need for skilled corrosion engineers and is the first university in the nation to offer a baccalaureate degree in corrosion engineering.

Capitalizing on this unique degree program, the U.S. Department of Defense awarded the University a grant to create the National Center for Education and Research on Corrosion and Materials Performance (NCERCAMP). NCERCAMP provides corrosion engineering research, testing and analysis to provide corrosion and materials performance solutions to industry and government agencies.

The center's more than 30 interdisciplinary professors and technicians are experts in a wide variety of engineering disciplines, including corrosion, chemical, surface, mechanical, civil, electrical and structural engineering, as well as polymer science, applied mathematics and statistics. This unique collection of skillsets allows the center to provide innovative solutions to a wide range of corrosion and materials performance issues.

For information on how to work with NCERCAMP on a project, please contact us at:

Address: NCERCAMP
264 Wolf Ledges Parkway
Akron, OH 44325

Telephone: 330-972-6978

Fax: 330-972-5141

Email: ncercamp1@uakron.edu

Website: uakron.edu/ncercamp

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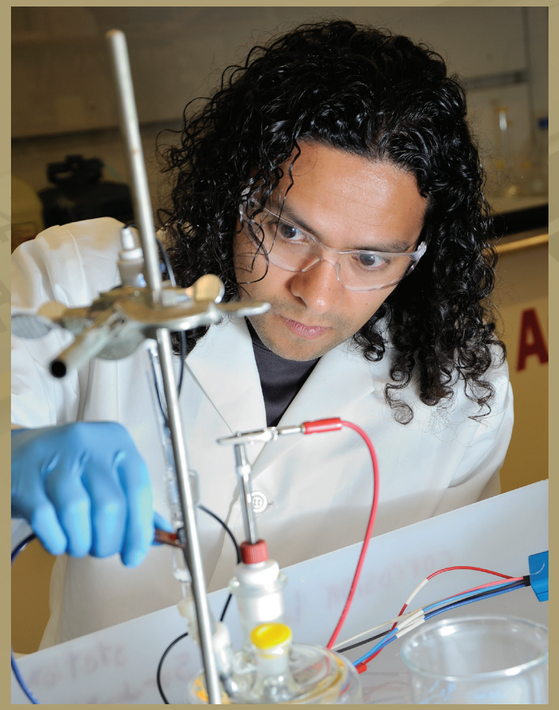
EQUIPMENT LIST

Equipment	Description
- Tescan LYRA-3 XMU FIB-FESEM System - Sputter Coater with Metal Vacuum Chamber	Microscopy observations, analytical compositional analysis
- Atomic Force Microscope with Multimode/Nanoscope	Materials Characterization, surface analysis (nano-scale) coupled with electrochemical measurements
- Micro hardness tester - Microscope for Coating Examination - Film Formation Bar - Stereoscopic Microscope – Olympus SZX16 - Inverted Microscope AmScope - Ultrasound Gauge, holiday detector, coating thickness gauge	Coatings sample preparation, coatings application and microscopy observations of coated materials, sample preparation for coatings performance tests
- Alicona InFocus G5 surface characterization - SEM Hitachi TM3030+ with EDS	Surface Characterization, microscopy observations with compositional analysis
- Rotating Cylinder Electrode (15-mm OD) - Gamry Potentiostats (4) - Biologic Potentiostats SP200 (2) - Biologic Potentiostat VSP300 4-channel - Modulab Solartron XM Electrochemical System	Wet chemistry, electrochemical characterization of materials by means of electrochemical techniques
- Salt spray chambers	Environment exposure, accelerated corrosion tests by aggressive environments
- Kelvin Probe with environmental chamber - Electrochemical Scanning System VersaScan (SECM, SVET, LEIS, SKP, SDC)	Electrochemical microscopy, surface analysis coupled with electrochemical testing
- QUV Accelerated weathering tester - QCT condensation tester	Temperature-relative humidity, coatings degradation tests by UV light and droplets condensation
- CSZ Temperature/Humidity tests	Sensors, controlled atmosphere tests
- Grips for Instron mechanical testing	Sensors, controlled atmosphere tests

Equipment	Description
- CORTEST frame for mechanical tests - 1 Gal Autoclave (Hastelloy) - 150,000 PSI Proof ring test system (mechanical testing) - Slow strain rate tests for mechanical testing (2)	Hostile environments, mechanical testing under high temperature/high pressure environments
- MTS Criterion C45.105 - MTS Landmark 370.10 with immersion bath chamber - Data Acquisition and MTS grips	Mechanical testing, materials are exposed to heavy loads or cyclic loads, mechanical performance of materials is tested
- High temperature vacuum furnace - High temperature 6 in. tube furnace - Furnace 1600C box furnace - Grinding bowl and tungsten ball mill - MTS Electromechanical mechanical test system - Micro-hardness tester	Composite materials, high temperature applications, materials performance at high temperatures
- CORTEST high purity autoclave	Autoclave, high temperature pressure tester
- Simultaneous TGA/DSC/DTA System	TGA, materials degradation, high temperature exposure
- Dell Precision Computers with specialized materials software: PANDAT, ELSYCA, OLI (6)	Modeling and simulation
- Struers Tegramin 30 polishing machines (2) - Buehler Abrasimatic 300 cutter	Sample preparation, sample cutting and grinding for electrochemical tests
- UV VIS Spectrophotometer - Force Tensiometer - Gamry 8-channel potentiostat	Materials development
- High energy ball mill	Materials development
- Fluorescence Microscope Olympus BX63 motorized XY stage	Materials development
- Automatic hydraulic press - Tube furnace with controlled atmosphere	Materials development
- Modeling software COMSOL	Modeling and simulation

EQUIPMENT LIST

Equipment	Description
- X-Ray computed tomography GE with dual tube	
- Temperature-relative humidity cabinet - Freeze thaw chamber	Controlled environment chambers
- Dedicated Acoustic Emission and resistance monitoring for burner rig	
- Gamry 600 potentiostats (4)	CAREs, electrochemical tests
- Hysitron Nano Mechanical test system	
- Scanning Auger Nanoprobe PH1710	
- PVD Deposition Chamber-Angstrom	



Postdoctoral researcher performs electrochemical testing.

Equipment	Description
- X-Ray Diffractometer-thin film	
- Oven for powder coatings - Mini temperature film formation bar - Climate chamber - Film drying Chamber-Keyence - Thinky centrifugal mixer - Viscosity Rheometer - CM-5 colorimeter - Dispermat CV3 - E-coater - FTIR Spectrometer - Hot air generator - Low temperature freezer - UV processor Omnicure S2000 - Convection oven BlueM - UV wet powder coatings processor with oven for UV-curable powder coatings - Sample cutter JDC Precision - Gardco Scrub resistance D10-VF - Film drying chamber machining and building Modern Tool Co. - Ross high sheer inline mixer - Film drying chamber humidity control system - VWR refrigerator/freezer	Coatings application and performance, materials development and performance
- Extensometer for MTS Burner Rig - HVOC for burner rig - Horizontal high temperature test instrument - DIC with thermal imaging for horizontal MTS - PPS thermal spray room High temperature tests, materials performance	High temperature test, materials performance
GAMRY 600 potentiostat with EQCM	Electrochemical tests
GAMRY 600 potentiostat	Electrochemical tests
Modeling software Biovia	Modeling and simulation

FACULTY AND KEY STAKEHOLDERS

Bastidas, David M.	Corrosion Engineering	- Corrosion of Steel in Concrete - Smart Corrosion Inhibitors - Stainless Steel Corrosion
Cheng, Gang	Chemical Engineering	- Biomolecular Engineering - Antimicrobial Hydrogels - Antifouling Hydrogels
Clemons, Curtis	Applied Mathematics	- Computational Mathematical Models of Corrosion Damage - Galvanic Corrosion, Crevice Corrosion - Biofilms
Cong, Hongbo	Corrosion Engineering	- Corrosion - Pitting - Passivity
Dhinojwala, Ali	Dean of College of Polymer Science and Polymer Engineering	- Surface Characterization - Plasma Coatings - Adhesion
Doll, Gary	Surface Engineering	- Surface Engineering of Materials - Tribology - Nanocomposite Materials
Evans, Ed	Chemical Engineering	- Curriculum Development - Environmental Barrier Coatings - Nanomaterials
Foster, Mark D.	Polymer Science	- Microstructure and Dynamics of Polymer Systems - Thin Films and Near Interfaces - Novel X-Ray and Neutron Scattering Techniques
Gao, Xiaosheng	Mechanical Engineering	- Mechanics of Materials and Structures - Fatigue and Fracture Mechanics - Multi-scale Modeling of Damage
Golovatv, Dmitry	Mathematics	- Mathematical Modeling of Corrosion Damage - Galvanic Corrosion - Crevice Corrosion, Biofilms
Gupta, Rajeev Kumar	Corrosion Engineering	- Novel Metallic and Ceramic Coatings - Passivity - High-Temperature Corrosion
Hernandez-Maya, Roberto	Research Scholar	- Electrochemistry - Corrosion - Surface Characterization
Huang, Qindan	Civil Engineering	- Risk Analysis, Structural Reliability - Performance Assessment of Deterioration Structures - Damage Detection Methods
Ida, Nathan	Electrical & Computer Engineering	- NDE and Sensors - AC Corrosion - Antennas

Students perform testing on coatings.

FACULTY AND KEY STAKEHOLDERS

Ju, Lu-Kwang	Chemical Engineering	- Microbiology - Biofilms and MIC - Fast Characterization of Pitting Corrosion
Kreider, Kevin	Mathematics	- Mathematical Modeling of Corrosion Damage - Galvanic Corrosion - Crevice Corrosion, Biofilms
Lillard, Scott	Corrosion Engineering	- Localized Corrosion - Passivity - Stress Corrosion Cracking and Hydrogen Damage
Menzemer, Craig	Structural Engineering	- Fatigue and Fracture of Structural Systems - Structural Behavior and Design - Material Characterization and Full-Scale Experimentation
Miller, Chris	Civil Engineering	- Water Quality Modeling and Management - Chemical Oxidation Process - Hydraulic Modeling
Mimoto, Nao	Statistics	- Statistics - Mathematics - Modeling Corrosion Damage
Monty, Chelsea	Chemical Engineering	- Advanced Electrochemical for Corrosion Prevention and Mitigation - Monitoring MIC
Morscher, Greg	Mechanical Engineering	- High-Temperature Oxidation and Corrosion - Stress, Time, Temperature, Environment Interaction and Mechanisms - High-Temperature Ceramic Matrix Composite Systems
Newby, Bi-min Zhange	Chemical Engineering	- Surface Modification/Patterning - Polymeric Materials - Anifouling Biofilms, MIC
Patnaik, Anil	Structural Engineering	- Corrosion Damage to Reinforced Concrete and Steel Structures - Life Cycle Analysis and Condition Assessment - Structural Engineering and Bridge Design and Construction

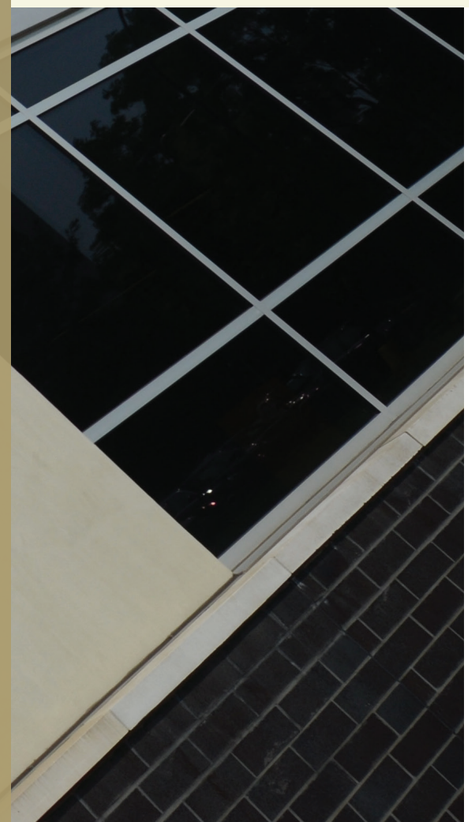
FACULTY AND KEY STAKEHOLDERS

Ramsier, Rex	Exec. Vice President, Principle Investigator	- Leadership - Surface Interactions (Metals) - Surface Science
Sastry, Shiva	Electrical Engineering	- Systems Analysis and Engineering - Wireless Monitoring Systems - Large-Scale Real-Time Systems
Senko, John	Geosciences	- Microbiology - Microbially Influenced Corrosion
Shiller, Paul	Surface Engineering	- Surface Engineering of Materials - Tribology - Nanocomposite Materials, Lubrication Strategies
Soucek, Mark	Polymer Science	- Corrosion-Resistant Coatings - Metal Cladding - Coatings Under Insulation
Srivatsa, Tirumalai	Mechanical Engineering	- Mechanical Behavior of Materials - Materials Processing and Characterization - Influence on Structural Response
Young, Gerald	Applied Mathematics	- Computational Mathematical Models of Corrosion Damage - Galvanic Corrosion, Crevice Corrosion - Biofilms
Zhe, Jiang "John"	Mechanical Engineering	- MEMS/NEMS and Lab-on-a-Chip Devices, Smart Materials and Structures - Micro/Nano Actuators, Microfluidics and Nanofluidics - Online Health Monitoring of Rotating Machinery
Zhou, Qixin "Amelia"	Corrosion Engineering	- Coatings Performance and Degradation Processes, Self-Healing Coatings - Water Treatment and Biodegradation - Electromagnetic Compatibility
Imes, Will	Senior Engineering Technician	- Project Management - Equipment Maintenance - Facilitator for Safe Working Practices and Environment
Li, Lingyan	Lab Technician	- Equipment Maintenance - Microscopy Technician - Equipment Training
Watkins, Katie	Office of Research Administration	- Financial Compliance - Financial Oversight - Equipment Fee Structure

CAPABILITIES

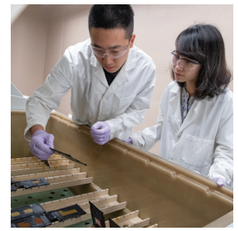
NCERCAMP draws from the expertise of more than 30 faculty members to provide corrosion and materials performance solutions to industry and government organizations. The center is home to a multimillion-dollar suite of equipment to provide research, testing and analysis in many ways.

Our capabilities are broadly outlined below.



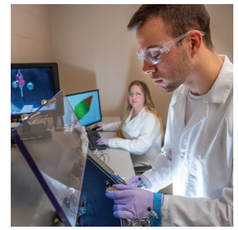
Materials Performance

- Accelerated Testing
- Mechanical Testing
- High-Temperature Testing



Materials Characterization

- Microscopy
- Spectroscopy
- Electrochemistry



Materials Development

- Coatings
- Alloys
- Composites

Modeling and Simulation

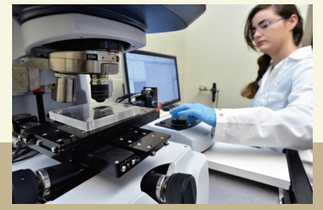
- Mathematical Models
- Atomistic Simulations

Microbially Influenced Corrosion (MIC)

- Characterization of Microbiological Activities
- Measurement of Chemical Indicators

MATERIALS PERFORMANCE TESTING

Testing is performed to understand corrosion and material degradation resistance of a variety of materials. Our wide range of testing equipment allows NCERCAMP researchers to accelerate corrosion processes while testing a material's mechanical properties and its performance in high-temperature environments.



A Corrosion Engineering student performs hardness testing on a micro-indenter

Accelerated Testing

- Expose coated and uncoated panels to aggressive environments to analyze corrosion resistance
- Accelerate damage and predict the material's performance
- Material degradation/corrosion processes are accelerated significantly under extreme environmental conditions
- Tests simulate effects of sunlight, dew and rain, generating weathering data in a few weeks or months
- Performance of metals, polymers and coatings for damage including color change, gloss loss, chalking, cracking, crazing, hazing, blistering, embrittlement, strength loss and oxidation

Mechanical Testing

- Evaluate electrochemical, physical and mechanical properties of coatings
- Qualification of hardness of films and coatings of materials varying from polymers to metals
- Determination of coating adhesion to substrate through nanoscratch testing
- Determination of coating failure mechanisms
- Highly localized determination of dynamic mechanical properties
- New techniques for testing reliability of commercial alloys
- Fatigue crack growth, high-cycle fatigue, low-cycle fatigue, fracture toughness, tension and compression

High-Temperature Testing

- Simulate operating stresses experienced in a pressurized water reactor system that is completely computerized
- High-temperature, high-velocity (up to Mach 2) burner rig testing with capability for sand ingestion
- Stressed oxidation testing under high-velocity, high-water-content atmosphere up to 1450°C
- Thermal-barrier-coated (TBC) superalloy system and ceramic matrix composite evaluation
- Understand influence of temperature on structure of metal
- Continuous measurement of oxidation kinetics as well as change in metal structure
- Heat treatments of materials in wide range of atmospheres and temperatures

MATERIALS CHARACTERIZATION

Materials characterization labs offer analytical instrumentation for liquid, powder, surface and bulk materials analysis and characterization. These resources are available to UA faculty members and students, outside researchers and industry.

The word "Akron" has been etched onto a sample using Focused Ion Beam technology on NCERCAMP's SEM. At only 10 µm, this etching is about 1/5 the thickness of a human hair.

Capabilities

- Corrosion analysis
- Elemental analysis
- 3D imaging
- In-air and in-liquid imaging
- Thermal processing and analysis
- Chemical composition
- Crystal structure
- Organic, inorganic, soft/hard materials, and coatings

Spectroscopy

- Auger Electron Spectroscopy (AES)
- X-Ray Photoelectron Spectroscopy (XPS)

Microscopy

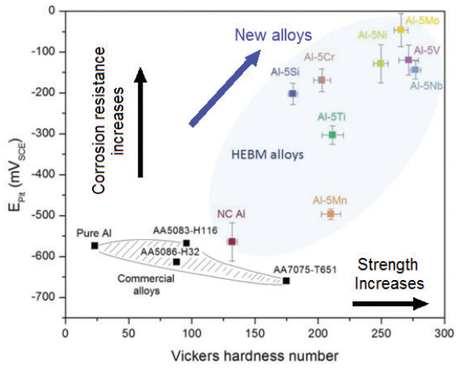
- Infinite Focus Microscope (IFM)
- Confocal Laser Scanning Microscopy (CLSM)
- Scanning Electron Microscopy/Energy Dispersive X-Ray (SEM/EDX)
- Atomic Force Microscopy (AFM)
- Kelvin Probe Force Microscopy (KPFM)
- Stereomicroscopy
- Fluorescence Microscopy
- Phase Contrast Microscopy
- X-Ray Diffraction (XRD)

MATERIALS DEVELOPMENT

NCERCAMP researchers strive to prevent corrosion before it begins, rather than merely manage it. For this reason, we are always working to develop new alloys, coatings, composites and other materials that offer superior corrosion resistance as well as outstanding mechanical properties.

Alloys and Composites

- Synthesis of advanced metallic materials with excellent corrosion resistance and mechanical properties
- Novel, ultra-strong, lightweight, corrosion-resistant materials for auto, marine and aerospace
- Processing technologies to improve the properties of commercial alloys
- Heat treatment of materials
- Metastable/nanostructured materials via high-energy ball milling
- Casting of various alloys and composites



Coatings

- Development of novel functional coatings with improved anti-corrosion properties and extended service lifetime
- Modification of polymer structure and performance
- Pigments for UV resistance
- Computational simulations/models to predict coating behavior
- Development of cure-on-command UV and visible light technology
- Synthesis of organic and inorganic coatings
- Metallic and ceramic coatings development

MODELING AND SIMULATION

NCERCAMP utilizes a number of different modeling and simulation software programs to develop, validate and apply mathematical models to predict, prevent and manage corrosion.

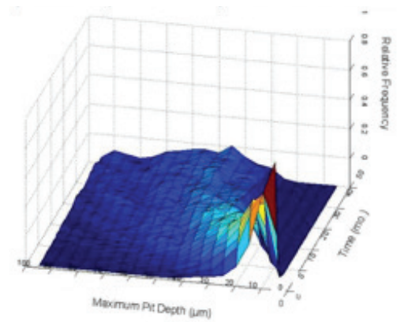
Capabilities

- Conducting coordinated experimental/modeling investigative approaches using interdisciplinary teams of mathematicians, statisticians, scientists and engineers. The approaches combine scientific concepts and empirical input
- Constructing atomistic, mesoscale and continuum scale simulations of deterministic and/or stochastic models for new or existing designs, and for risk analysis
- Developing analytical solutions and/or numerical simulations (using in-house or commercial computational codes)
- Elucidating the interaction between the environment and the dynamic response of the system

Applications

- Atomistic simulations of surface layers, inner layer coatings, and binding of coatings to metals
- Crevice corrosion of corrosion-resistant alloys in fastener assemblies
- Galvanic corrosion in a variety of industrial metallic configurations
- Pitting corrosion
- Combined galvanic, crevice and pitting corrosion
- Microbially influenced corrosion (MIC) and biofilms
- Corrosion in coating/metal systems

Risk Management of Pitting Corrosion (AA1050) in Atmospheric Conditions



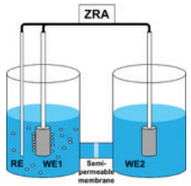
MICROBIALLY INFLUENCED CORROSION (MIC)

Researchers at UA are characterizing the influences of various microbiological processes on the corrosion of various alloys. We apply a unique combination of innovative electrochemical and microbiological techniques to determine mechanisms and early indicators of microbially influenced corrosion (MIC).

UA Research

- Apply a variety of approaches to understand the roles of microorganisms in corrosion
- Use model microorganisms, organisms isolated from systems experiencing MIC, and mixed microbial consortia from those systems
- Study microorganisms in situ, including measurements of chemical indicators of microbiological activities and culture-independent approaches to characterizing microbial communities and activities
- Utilize microscopic approaches to surface characterization, and electrochemical approaches to interrogating fluid chemistry and solid-solution interfaces (e.g., LP, EIS).

The "ZRA" Technique



- Interrogate MIC in a split-cell format
- Zero-resistance ammetry (ZRA) measurements are collected from two working electrodes (WE) deployed in separate chambers that are connected by a semipermeable membrane
- Mimic the conditions associated with heterogeneous coverage of metal surfaces by microbial biofilms, while adapting the physicochemical conditions to those observed in field settings
- Monitor processes that occur when metals are exposed to different environmental conditions
- UA researchers are currently using this technique to:
    1. Determine mechanisms of MIC
    2. Develop robust rate formulations for MIC
    3. Sensitively monitor MIC in real time

Testing Agreements – Testing agreements are generally short-term engagements. Organizations will specify requirements, such as what materials they would like to have tested and what testing methods they are looking for. The center will then carry out testing and provide the results to the client. No analysis is performed.

Master Research Agreements – Research agreements are typically long-term. Companies will come to us to help find solutions to their corrosion problems. This may involve the sponsorship of a student or a postdoctoral researcher. As the research is conducted, NCERCAMP will provide an analysis of the findings and will provide ongoing recommendations.

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