Advanced Materials and Structures

S. Pamir Alpay

Executive Director – UConn Innovation Partnership Building at UConn Tech Park

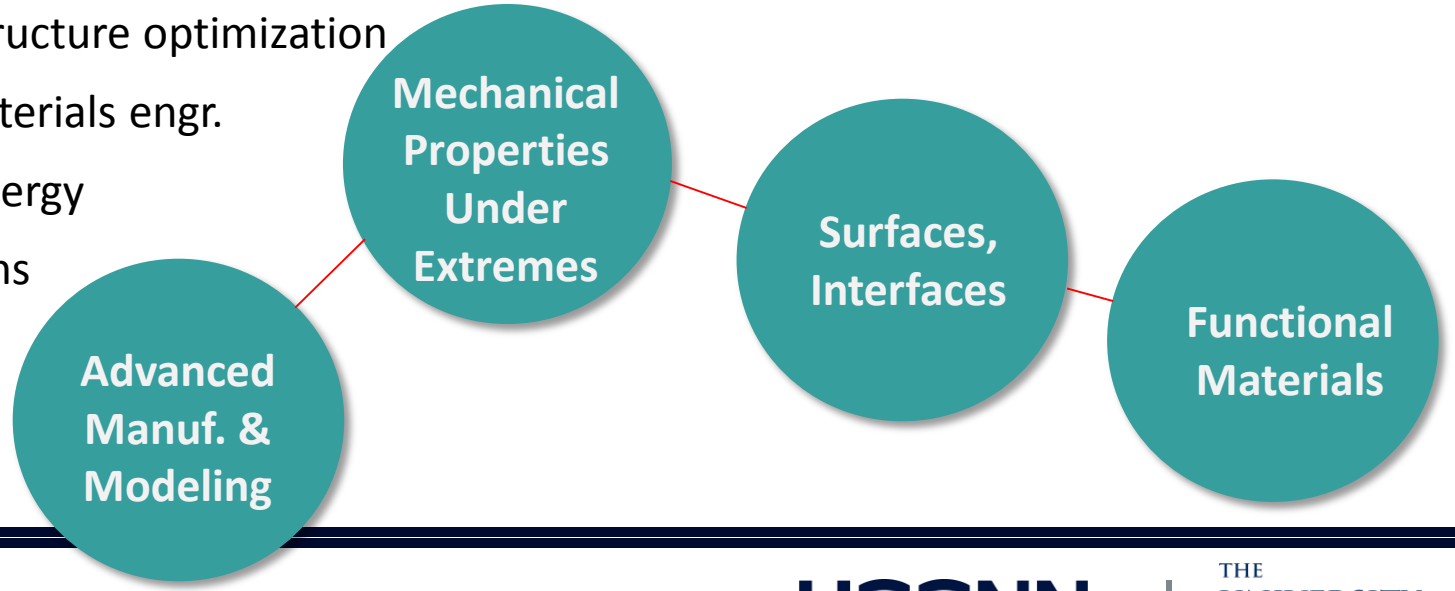
General Electric Professor in Advanced Manufacturing

Professor of Materials Science & Engineering

Advanced Materials – An Excellent Team…

Interdisciplinary & Complimentary Faculty Expertise at Both Institutions…

- S. Pamir Alpay (UConn, team lead) – Materials modeling, functional materials
- Arun Shukla (URI) – Materials under extreme conditions, shock loading
- Rainer J. Hebert (UConn) – Metallurgy and metal AM
- David Taggart (URI) – Composite Materials, modeling
- Steven L. Suib (UConn) – Ceramics, catalysis, interfaces, surfaces
- Julian Narato (UConn) – Composite structures, structure optimization
- Serge Nakhmanson (UConn) – Computational materials engr.
- Jasna Jankovic (UConn) – Electron microscopy, energy
- Jeongho Kim (UConn) – Manufacturing simulations



Advanced Materials – Strengths and Facilities

Strengths

- Advanced Materials Characterization
- Metal and Polymer Additive Manufacturing
- Custom Alloy Design
- Manufacturing and Processing Simulations
- Composite Materials and Structures
- Materials under Extreme Conditions
- Surface and Interface Properties
- Functional Materials
- Computational Materials Engineering
- Materials Data

State-of-the-Art Facilities

- URI CoE & UConn SoE
- Institute of Materials Science at UConn
- UConn Innovation Partnership Building / Tech Park

Faculty Expertise: S. Pamir Alpay (UConn)

S. Pamir Alpay
Professor of Materials Sci. & Engr.
Executive Director – UConn Tech Park
University of Connecticut
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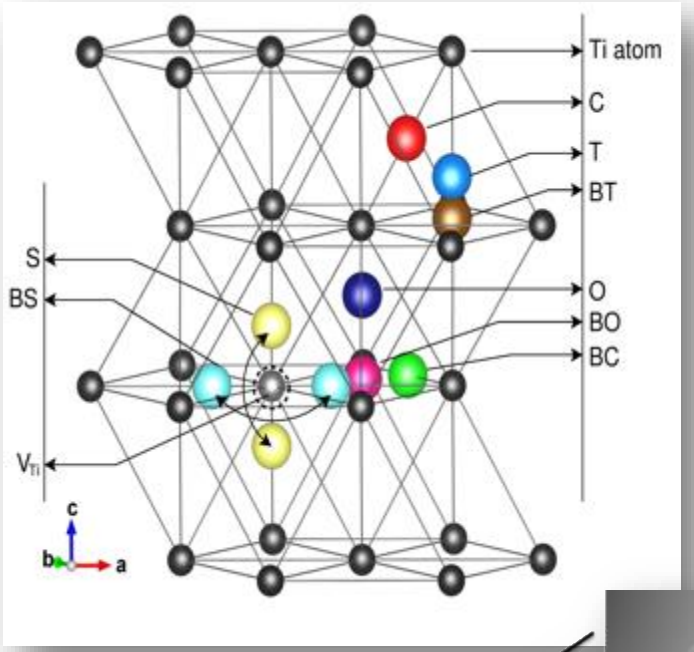
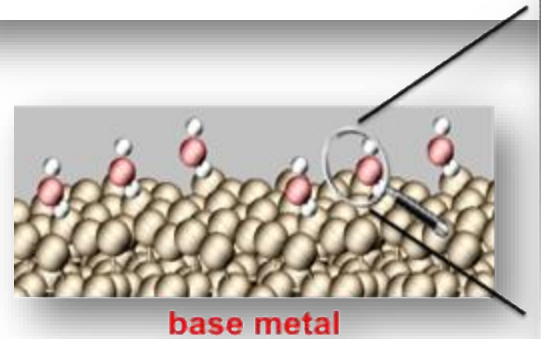
pamir.alpay@uconn.edu

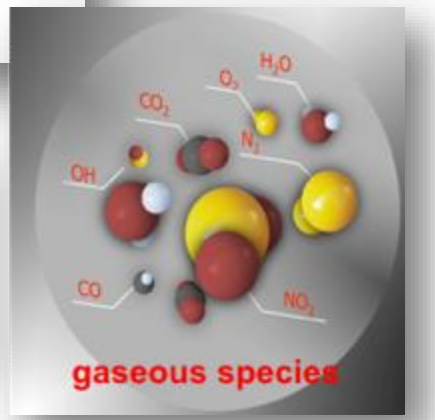
Research Interests

- Materials modeling
- Computational materials science
- Functional Materials
- Metallurgy
- Materials by design
- Piezoelectrics
- Dielectrically tunable materials for telecommunications
- Conducting oxides
- Materials for solid state heating/cooling



Modeling of defects and surfaces of base metals



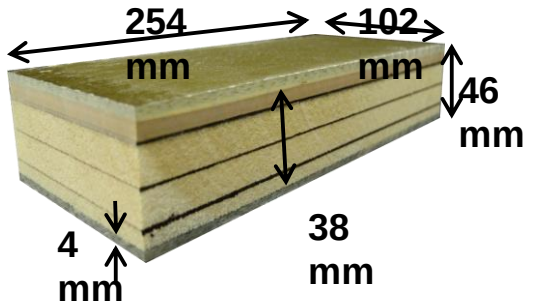


Faculty Expertise: Arun Shukla (URI)

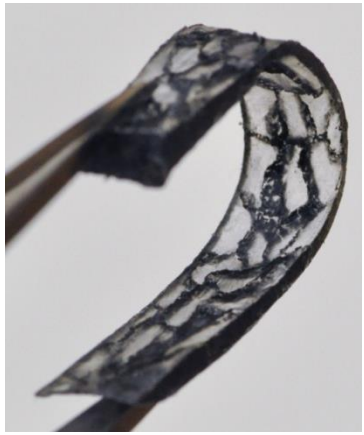
Arun Shukla
Simon Ostrach Professor
Mechanical, Industrial & Systems Engr.
University of Rhode Island
Kingston, RI 02881
Ph.: (401) 874-2283
Email: shuklaa@uri.edu

Research Interests

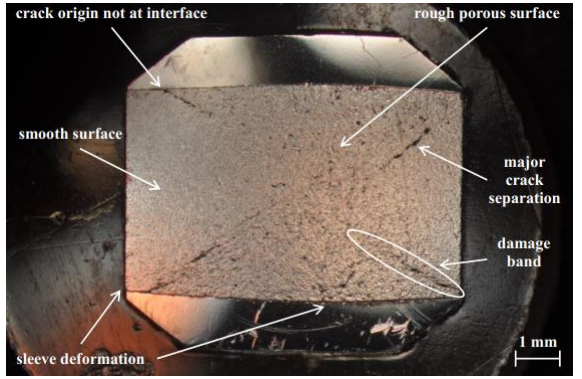
- Dynamic Response of Materials
- Multifunctional Materials
- Composite Materials
- Functionally Graded Materials
- Hybrid Materials
- Materials for Extreme Loadings
- Max Phase Materials



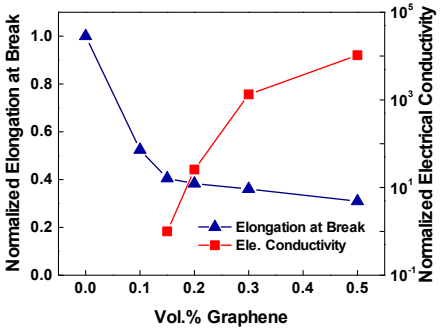
Composite Sandwich Materials



Highly Flexible Graphene-Polymer Templated Composites



Max Phase Material Dynamic Response



Electro-mechanical Behavior of Templated Materials

NATIONAL INSTITUTE FOR UNDERSEA VEHICLE TECHNOLOGY

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Faculty Expertise: Rainer J. Hebert (UConn)

Rainer Hebert
Castleman Associate Professor of Materials Sci. & Engr.
Director, Pratt & Whitney Additive Manufacturing Center
Associate Director, Institute of Materials Science
University of Connecticut
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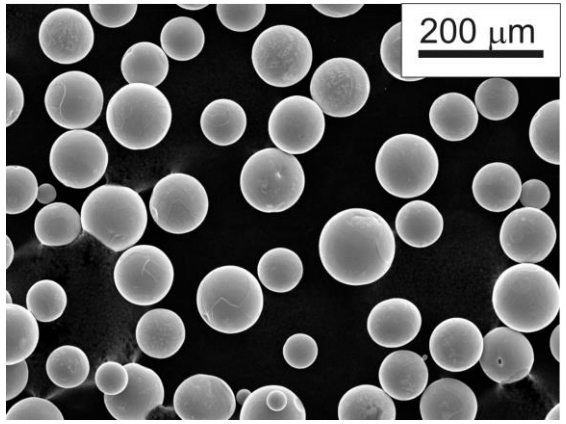
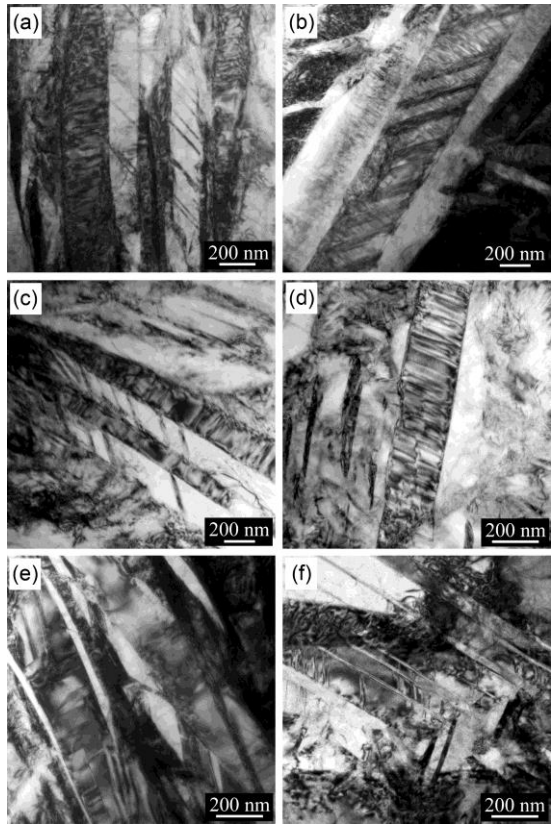
Research Interests

- Metal additive manufacturing
- Thermophysical property measurements
- Rapid solidification processing



Scanning electron microscopy image of Ti-6Al-4V powder particles (with Dr. Yu Sun, UConn)

Gleeble 3500 system for thermophysical simulations



TEM images of rapidly quenched Ti-6Al-4V powder; (a)-(f) powders from different vendors

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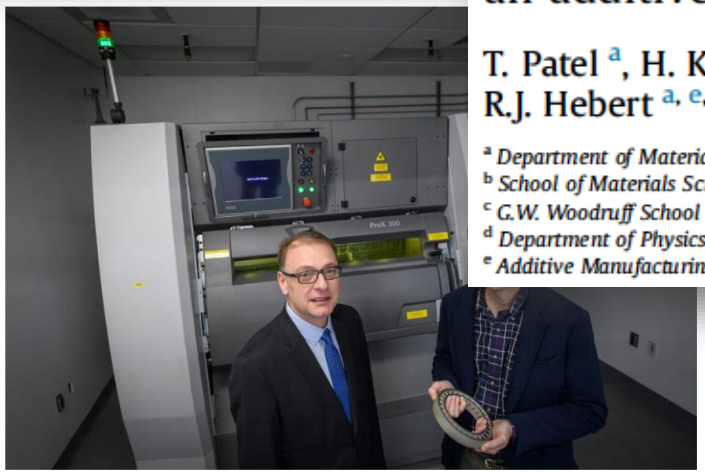
Faculty Expertise: Rainer J. Hebert (UConn)

UConn T

RESEARCH SCIENCE

Full Speed Ahead: Usir Manufacturing to Repa

December 20, 2017 - **Office of the Vice President for Research**



Researchers Pamir Alpay, left, and Rainer Hebert, hold a sample of 3-D metal printing at UConn's Innovation Partnership Building. (Peter Morenus/UConn Photo)

location of any mechanical trouble on board and, instead of taking the ship offline for maintenance, to repair or replace the part while the ship is still at sea.

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journal homepage: www.elsevier.com/locate/actamat

Full length article

Metalorganic solution deposition of lead zirconate titanate films onto an additively manufactured Ni-based superalloy

T. Patel [a], H. Khassaf [a], S. Vijayan [a], N. Bassiri-Gharb [b, c], M. Aindow [a], S.P. Alpay [a, d], R.J. Hebert [a, e, *]

[a] Department of Materials Science and Engineering and Institute of Materials Science, University of Connecticut, Storrs, CT, USA
[b] School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, GA, USA
[c] G.W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA, USA
[d] Department of Physics, University of Connecticut, Storrs, CT, USA
[e] Additive Manufacturing Innovation Center, University of Connecticut, Storrs, CT, USA

Fig. 4. Overlay of the STEM compositional maps for Pb, Zr, Ti, Ni, Cr, Fe and O, from Fig. 3(b–h), respectively. The highlighted regions 1–6 are the areas over which data was integrated to obtain the metal/cation compositions given in Table 1.

Faculty Expertise: Jeongho Kim (UConn)

Jeongho Kim
Director of Connecticut Manufacturing Simulation Center
Associate Professor of Department of Civil & Environmental Engineering
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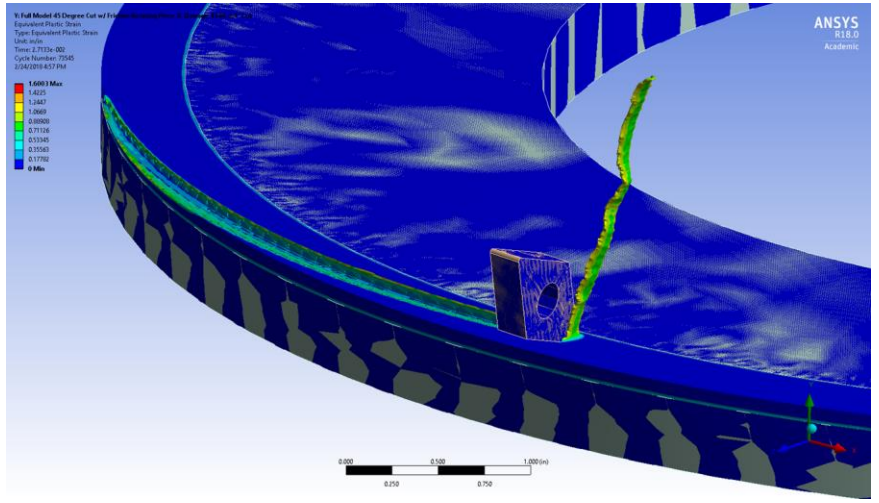
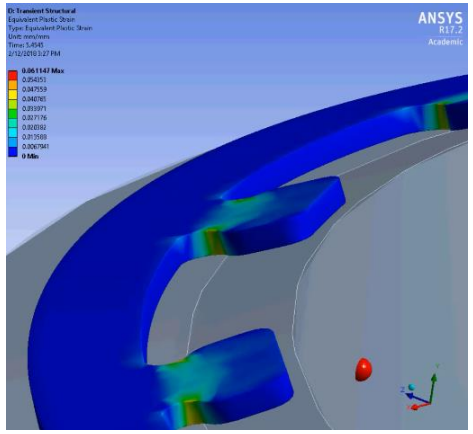
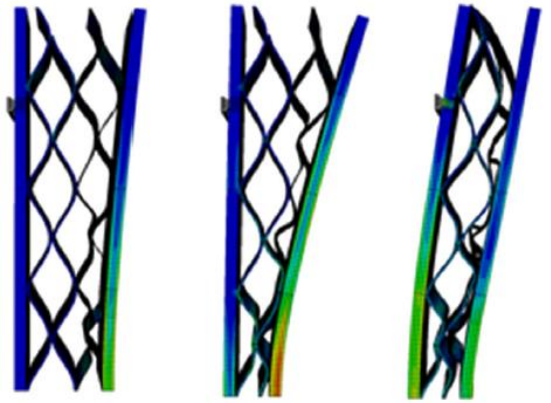
Research Interests

- Finite Element Modeling
- Thermomechanical Analysis
- Damage & Fracture Modeling
- Manufacturing Simulations
- Machining Simulation (Metals)
- Heat Treat Modeling (Metals)
- Distortions & Residual Stresses
- Composites Damage Modeling
- Modeling of Functionally Graded Materials







Faculty Expertise: Serge Nakhmanson (UConn)

Serge Nakhmanson
Associate Professor of Materials Sci. & Engr. and Physics
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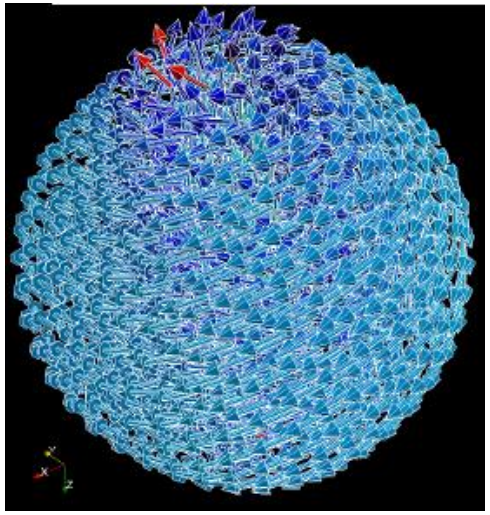
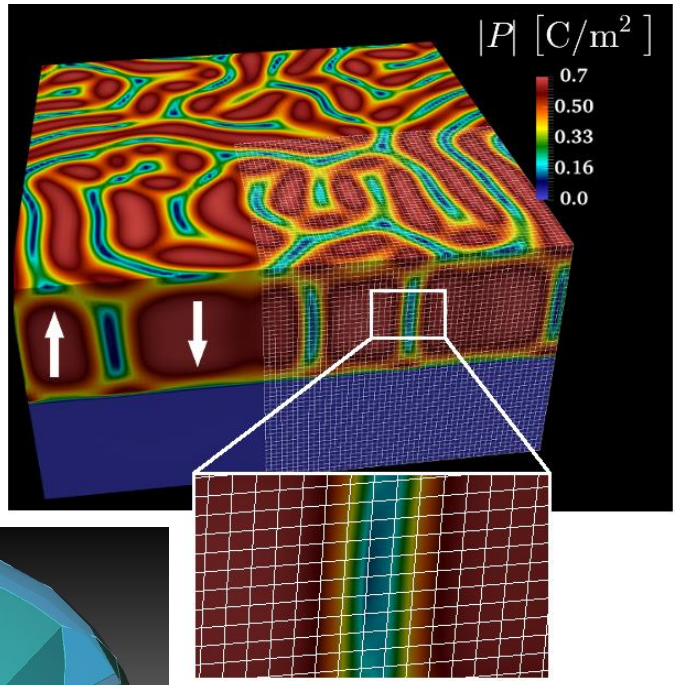
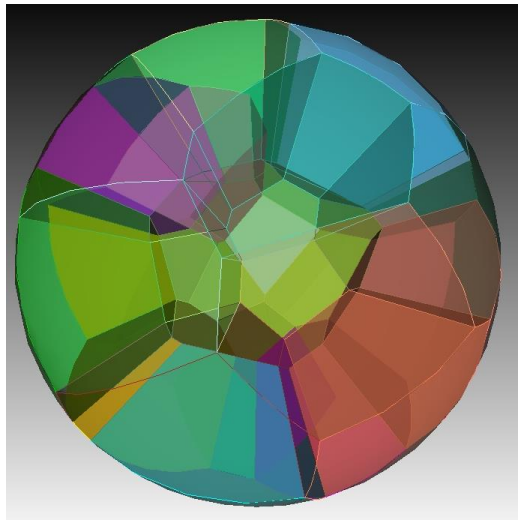
Research Interests

- Materials modeling
- Computational materials science
- Finite element method based materials simulations
- Machine learning and data mining
- Functional dielectrics: oxides, polymers, molecular crystals
- Semiconducting nanostructures
- Reconfigurable optical materials







Mesoscale level modeling of functional materials and nanostructures

NATIONAL INSTITUTE FOR UNDERSEA VEHICLE TECHNOLOGY

UCONN SCHOOL OF ENGINEERING | THE UNIVERSITY OF RHODE ISLAND COLLEGE OF ENGINEERING

Faculty Expertise: Julián Norato (UConn)

Julián Norato
Assistant Professor
Mechanical Engineering
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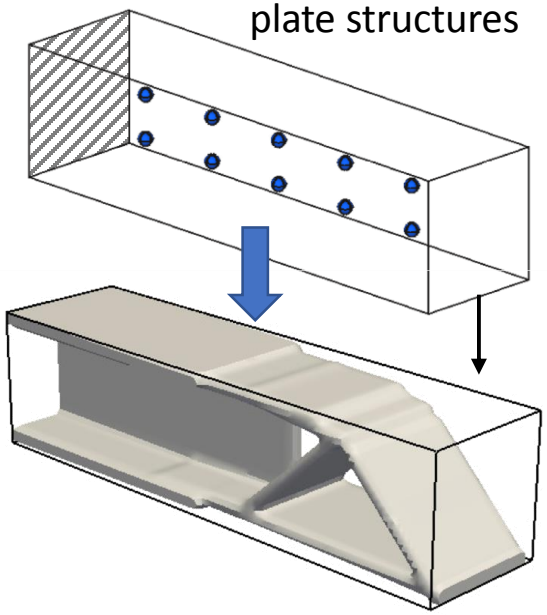
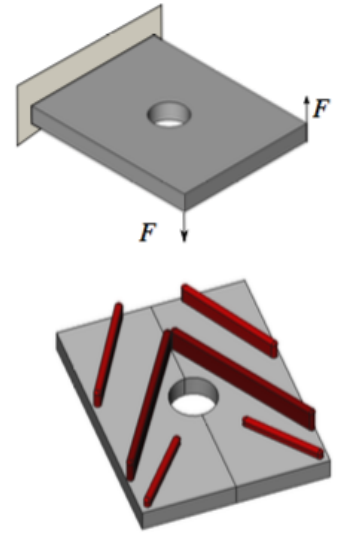
Research Interests

- Topology and shape optimization
- Computational design of structures with manufacturing-driven constraints
- Design of cellular solids, including architected lattice and sandwich structures
- Design with composite materials
- Stress and fatigue criteria in topology optimization
- Patient-specific bone scaffolds

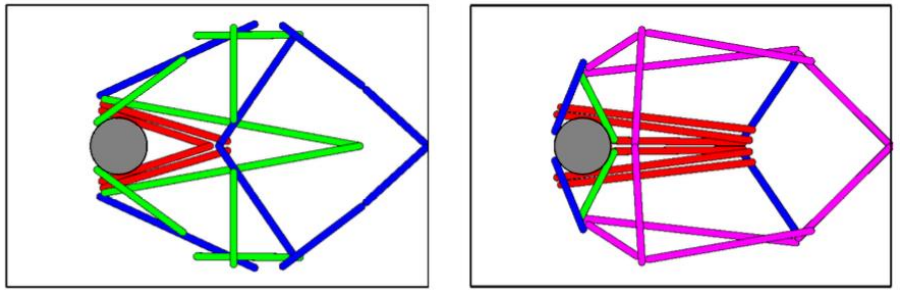
Topology optimization of plate structures



Optimal rib layout for panel reinforcement



Design of multi-material lattice structures



Faculty Expertise: David G. Taggart (URI)

David G. Taggart
Professor of Mechanical Engineering
University of Rhode Island
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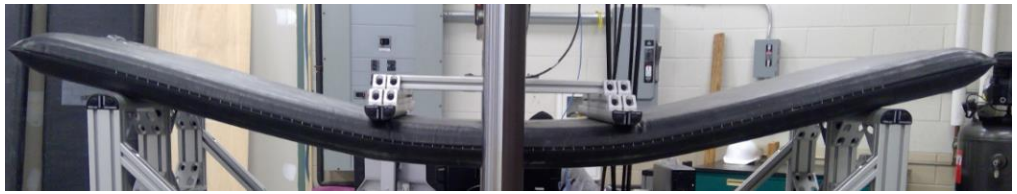
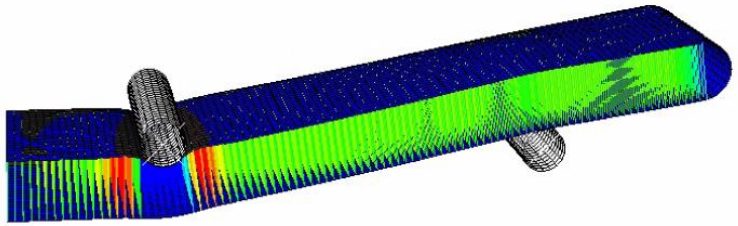
Email: taggart@uri.edu

Research Interests

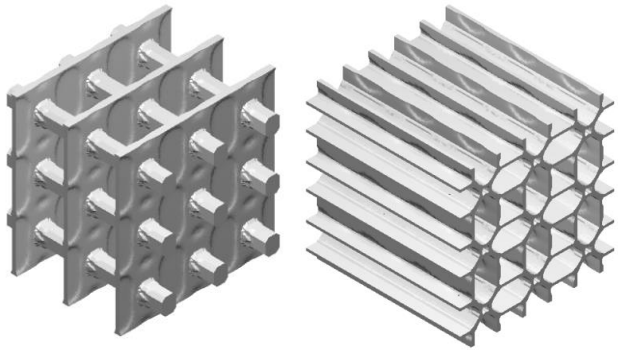
- Computational solid mechanics
- Mechanics of inflatable structures
- Finite element based topology optimization
- Design of lightweight structures
- Mechanics of composite materials
- Abrasive waterjet machining
- Waterjet nozzle wear





Characterization and numerical simulation of inflatable panel

Abrasive waterjet nozzle wear pattern



Optimized lattice structures

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UCONN SCHOOL OF ENGINEERING | THE UNIVERSITY OF RHODE ISLAND COLLEGE OF ENGINEERING

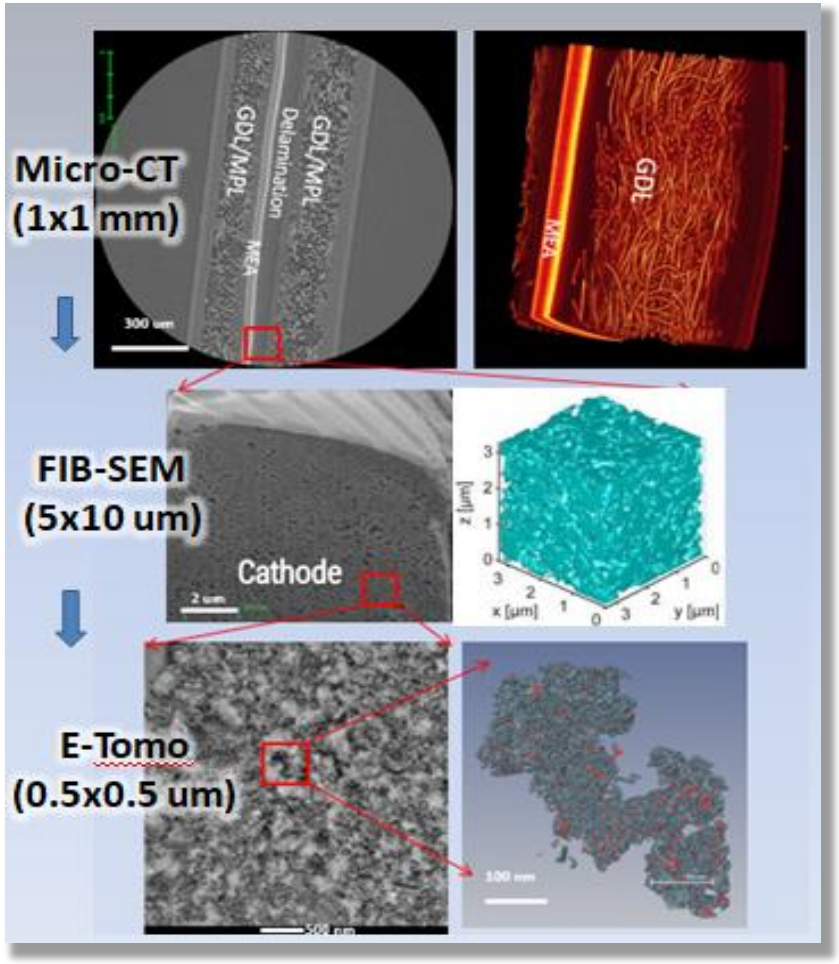
Faculty Expertise: Jasna Jankovic (UConn)

Jasna Jankovic
Assistant Professor
Materials Science & Engineering
Institute for Materials Science
Center for Clean Energy Engineering
University of Connecticut
Jasna.jankovic@uconn.edu

Research Interests

- Advanced (3D) Imaging and Spectroscopy
- Nanomaterials for Clean Energy Applications
- Fuel Cells
- Batteries
- Electrospinning
- Structure-Property-Performance Correlations

3D multi-scale imaging and simulation

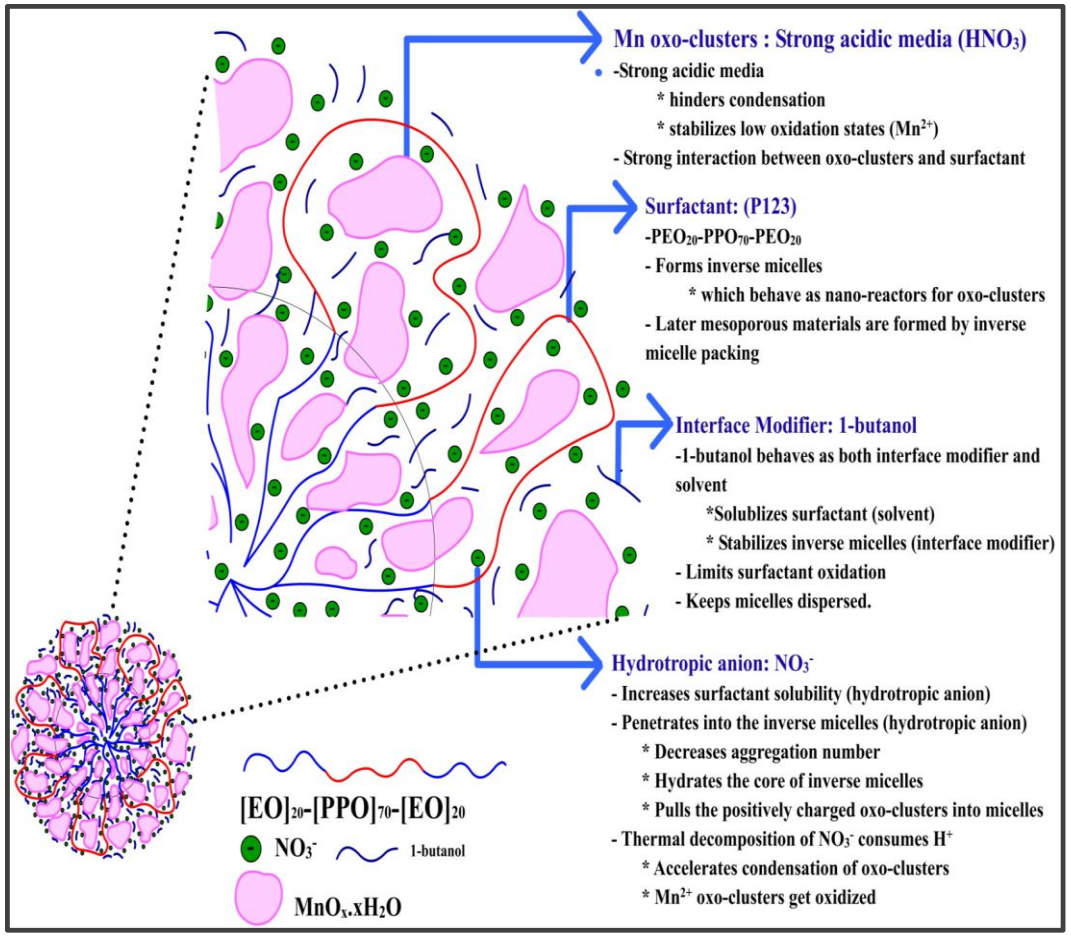


Faculty Expertise: Steven L. Suib (UConn)

Steven L. Suib
Board of Trustees Distinguished Professor of Chemistry
Director, institute of Materials Science
University of Connecticut
Voice: (860) 486-2797
Steven.Suib@uconn.edu

Research Interests

- Catalysis
- Ceramics
- Nanomaterials
- Spectroscopic Methods
- Electron Microscopy
- Composites
- Conducting oxides
- Environmental Chemistry
- Semiconductors



Inverse micelle procedure for making porous metal oxides

Advanced Materials – Strengths and Facilities

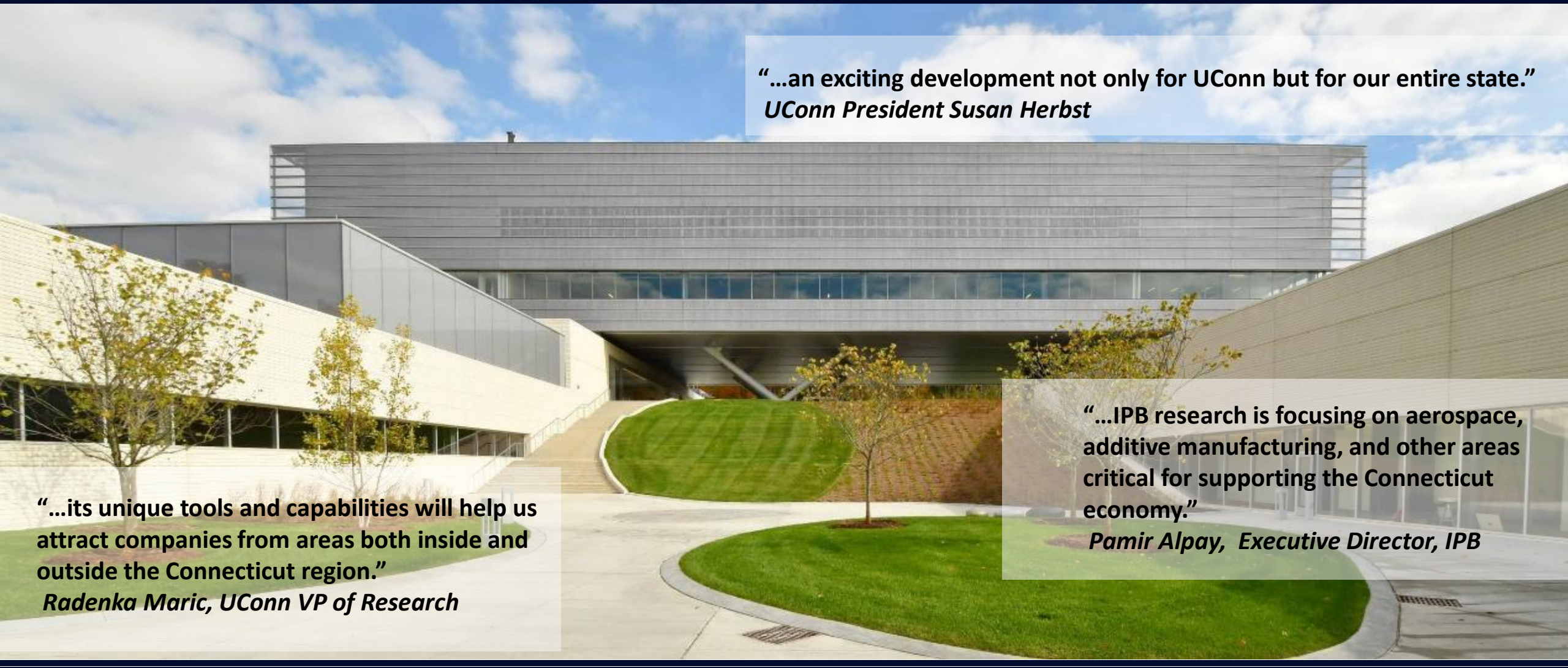
Strengths

- Advanced Materials Characterization
- Metal and Polymer Additive Manufacturing
- Custom Alloy Design
- Manufacturing and Processing Simulations
- Composite Materials and Structures
- Materials under Extreme Conditions
- Surface and Interface Properties
- Functional Materials
- Computational Materials Engineering
- Materials Data

State-of-the-Art Facilities

- URI CoE & UConn SoE
- Institute of Materials Science at UConn
- UConn Innovation Partnership Building / Tech Park

INNOVATION PARTNERSHIP BUILDING AT UCONN TECH PARK



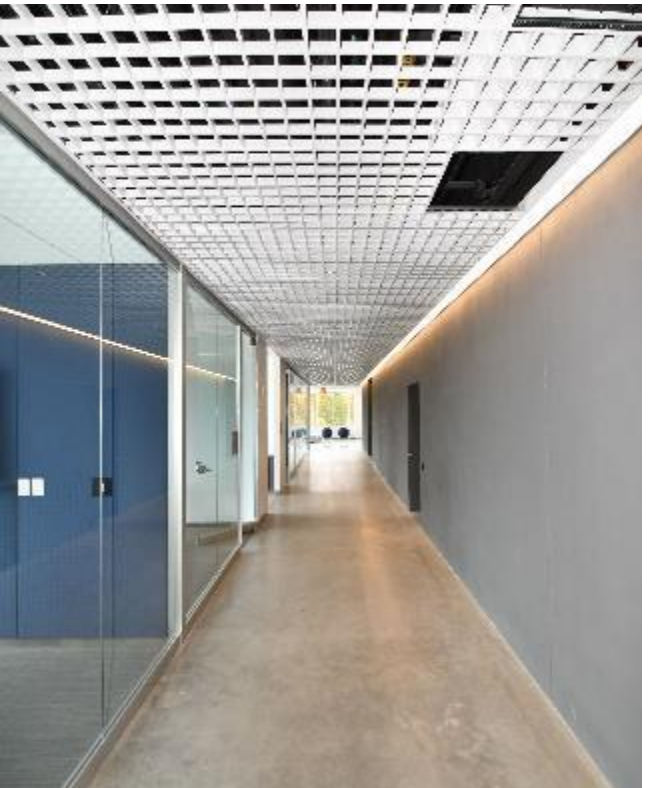
"…an exciting development not only for UConn but for our entire state."
UConn President Susan Herbst

"…its unique tools and capabilities will help us attract companies from areas both inside and outside the Connecticut region."
Radenka Maric, UConn VP of Research

"…IPB research is focusing on aerospace, additive manufacturing, and other areas critical for supporting the Connecticut economy."
Pamir Alpay, Executive Director, IPB

NATIONAL INSTITUTE FOR UNDERSEA VEHICLE TECHNOLOGY

UCONN SCHOOL OF ENGINEERING | THE UNIVERSITY OF RHODE ISLAND COLLEGE OF ENGINEERING



IPB Factoids

PARTNER WITH UCONN

Leverage these distinctive IPB assets:

- **World class faculty with diverse research interests**
- **State of the art equipment and laboratories**
- **Collaborative, innovative and entrepreneurial ecosystem**

INVESTED IN THE FUTURE

$ 100M

Invested in the IPB building project

$ 40M

Invested in state of the art research equipment

$ 30M

Invested in roads and site improvements

STATE OF THE ART FACILITY

The IPB is an innovative, exciting focal point at the forefront of research, instituting a far-reaching network of resources, programs and collaborations that extend throughout the State of Connecticut and beyond.

FEATURES

113,700

square feet the three floors

3,800

feet from main campus (North Hillside Road)

WEATHER FORECASTING

1.8 million

Eversource power customers benefit from UConn's Outage Prediction Model, the first of its kind to be developed at the Eversource Energy Center. Developing the model required analyzing megabytes and terabytes of power infrastructure data.

MATERIALS TESTING

10 tons

static force can be exerted by the Gleeble 3500, a sophisticated simulator that is applied in industry to explore new production techniques, potentially reducing development timelines and cutting production costs.

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IPB Factoids

MAJOR INDUSTRY PARTNERS

10

major industry partners committed more than $80 million in funding to advance research at UConn.

ADVANTAGES

MICROSCOPY

100+ million

times magnification capability of Titan Themis TEM, FEI's flagship microscope, allowing scientists to see individual atoms and evaluate their properties. UConn houses one of the world's foremost facilities for electron microscopy.

DRIVING INNOVATION & COLLABORATION IN CT

8,000

companies within two hours' drive to UConn perform work relevant to the IPB, with research applications in clean energy, medical devices, aerospace, cybersecurity, and more.

The IPB foundation extends as much as

15

minute walk from campus

80

feet underground to maintain stability of equipment that is highly sensitive to vibrations such as the precision lasers and highly sensitive electron microscopes housed in the Advanced Characterization Lab (ACL).

NATIONAL INSTITUTE FOR UNDERSEA VEHICLE TECHNOLOGY

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Institute of Material Science (IMS)

IMS History & Mission

- The largest interdisciplinary center at UConn
- Operating continuously since 1965
- Established by charter from the CT General Assembly
- Mission is to serve as a focus for research, graduate education, industrial collaboration and community outreach in all aspects of materials science

IMS Facility

- Core of IMS housed in a 95,000 ft2 wing of the Gant Science Complex on the Storrs main campus. The building houses:
- 40 faculty, 40 staff and 100 graduate students
- Faculty research laboratories
- Central shared-use instrumental research facilities
- Three graduate programs (Mat Sci, MSE & Polymer Sci)
- Industrial programs (IMS Industrial Affiliates, EIRC)

Institute of Material Science (IMS)

RESEARCH THRUSTS

- Additive Manufacturing
- Biomaterials, Biomedical Devices
- Catalysis and Solid State Chemistry
- Ceramics, Coatings and Composites
- Computational Modeling
- Condensed Matter Physics
- Electronic and Optoelectronic Materials
- Materials Characterization
- Metals and Alloys
- Polymers

Thermo Fisher Scientific Center of Advanced Microscopy and Materials Analysis (CAMMA)

15 Year UConn-FEI Partnership, Est. Nov 2014

- Investment: $25M
- One of the world's foremost facilities for electron microscopy
- Cutting edge R&D applications in
  - New material development (materials genomics)
  - Advanced manufacturing
  - Electronics integrity testing
  - Biological agent detection
  - Vaccine development
  - Tissue engineering
- New funding opportunities through federal agencies and industry sponsors

UConn Thermo Fisher Scientific Center of Excellence

- $12 M in instrumentation
- 7 new state-of-the art instruments
- Facility Staff Scientist & Half-time Field Service Engineer
- Research funding ($400k/year - 5 year min.)
- Graduate scholarships ($50/year - 5 year min.)
- Training of staff
- Engagement contributions

CAMMA Phase 1 Instruments

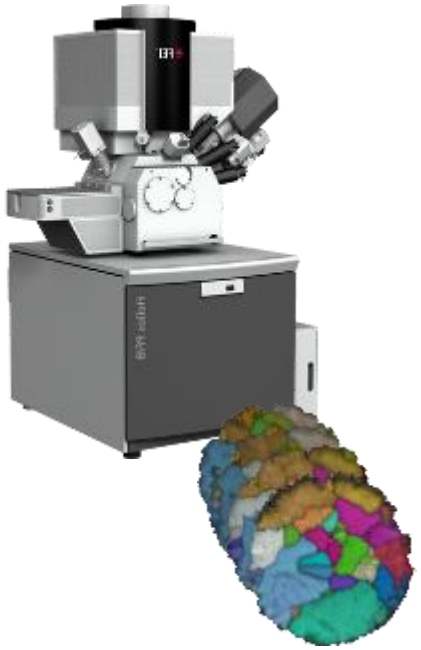
Talos F200X

Energy Dispersive Spectroscopy STEM

Atomic resolution EDS map of alternating rows of calcium and iron atoms

Helios PFIB

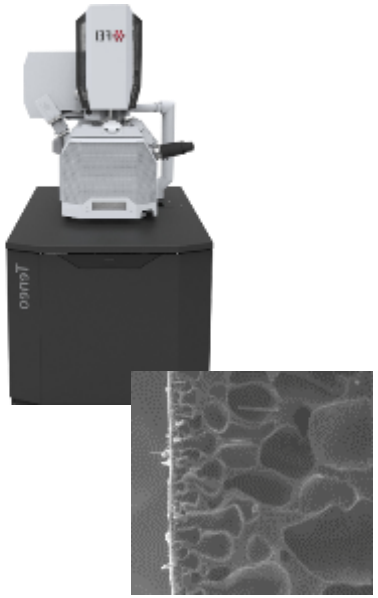
Plasma Focused Ion Beam/Field Emission SEM



Serial milling with 3D EBSD acquisition

Teneo LoVac

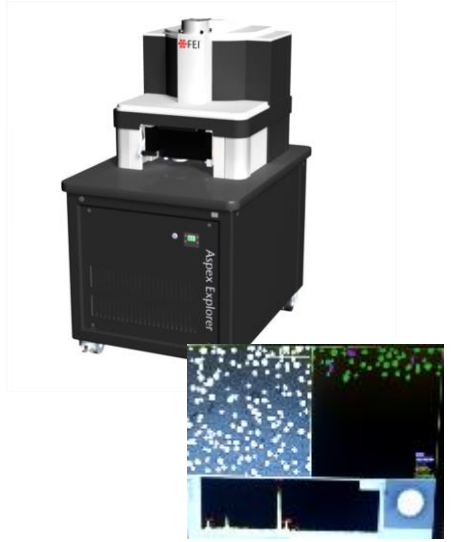
SEM for Material Science



Basketball (uncoated) cross section

Aspex Explorer

Analyzer for size, shape and composition



Automated particle size and chemistry analysis

Helios Nanolab 460F1

Focused Ion Beam/SEM

STEM image of FIB prepared TEM lamella

CAMMA Phase 2 Instruments

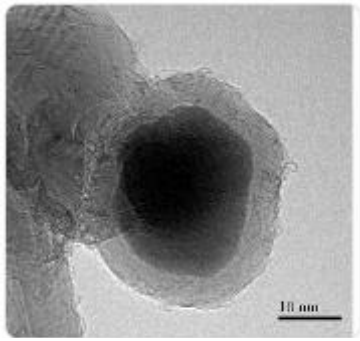
Verios 460L

Environmental SEM for Biological Samples

SEM - Biopolymer Mesh for Wound Healing

Titan Themis

Atomic Scale S/TEM



TEM - Carbon Nanotubes

Reverse Engineering Fabrication Inspection & Non-destructive Evaluation (REFINE) Lab

Applications

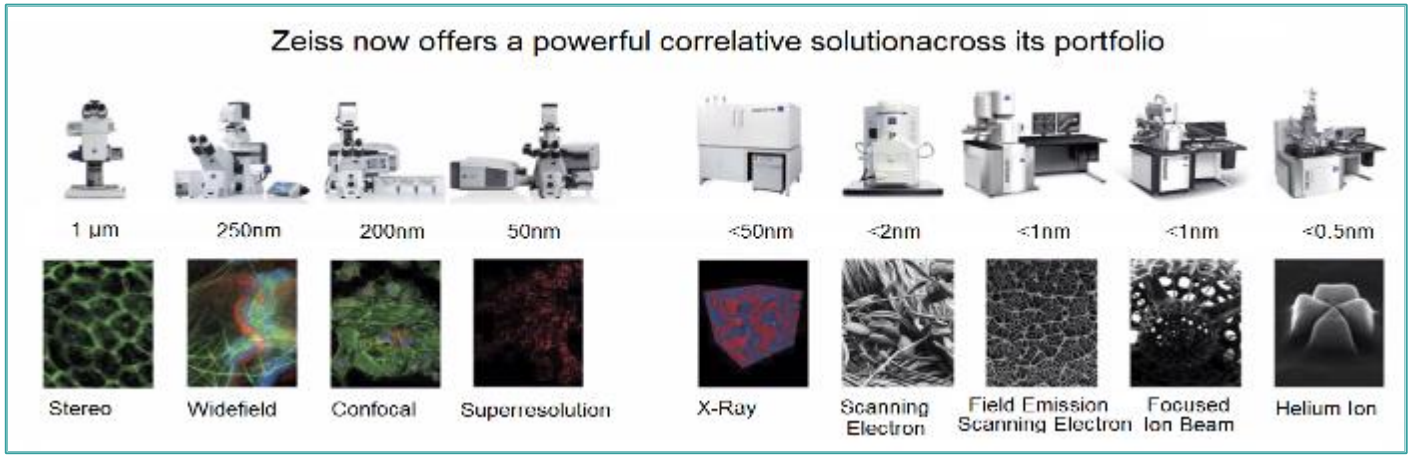
- Hardware Security
- Circuit Edit and IC debugging
- Semiconductor and Lithography
- Batteries and Energy Storage
- Failure Analysis and Forensic Analysis
- Advanced Coatings
- Biomedical Devices

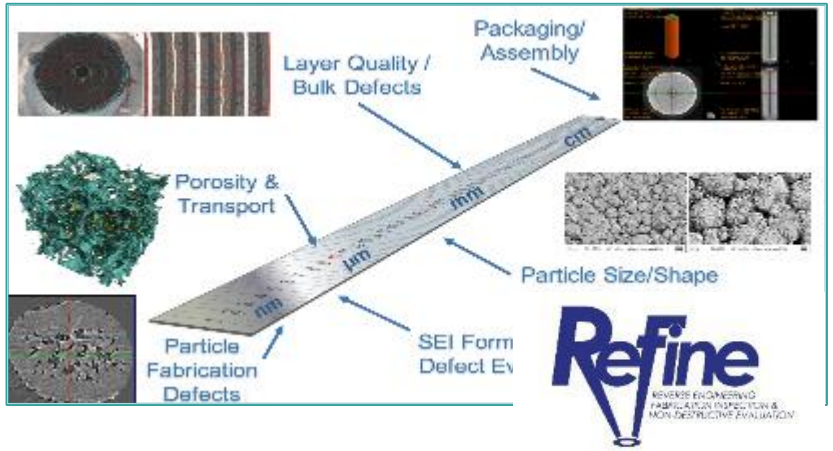
Key Components of ZEISS Partnership

- Access to the entire ZEISS portfolio in NY, MA, and CA.
- Research Funding on Correlative Microscopy
- Advanced Training
- Premium Service maintaining high uptime
- ZEISS Beta Site and early adopter

Methods

- 3D X-ray Tomography
- 3D FIB Tomography
- 3D EDS
- 3D SEM Imaging
- Non-destructive Methods
- Correlative Microscopy
- In Situ Imaging
- Computational Microscopy
- Light and Confocal Microscopy





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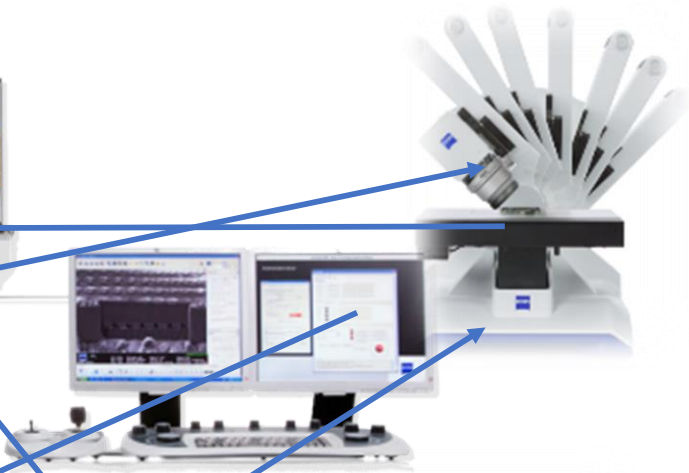
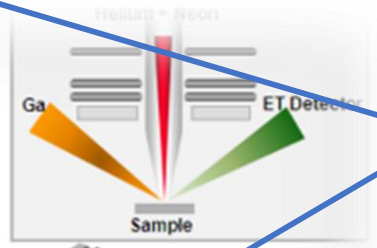
REFINE Lab – Correlative Microscopy

Smart PROOF 5

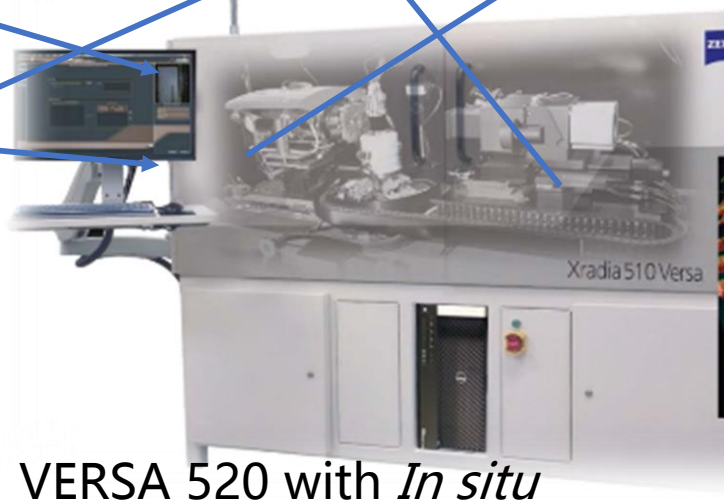
Crossbeam 340 with Laser ablation

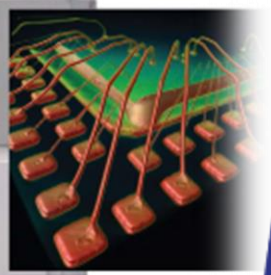


Smart ZOOM 5



Orion Nanofab





VERSA 520 with *In situ*

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UConn Additive Manufacturing Center (AMC)

Key Research Focus Areas

Alloy development

- Project features: Complex, yet fundamental research topics: Hot tearing, rapid solidification, precipitation reactions, computational materials engineering
- **Unique features of IPB**: Electron microscopy, laser equipment, arc-melter, Gleeble
- Leverage: Very high leverage, use for new proposals (AFRL, Navy Underwater Vehicle, etc)

Thermo-physical properties/manufacturing data

- Project features : Expertise required for measurements, computational material data, several alloy systems, manufacturing conditions.
- **Unique features of IPB**: Suite of thermophysical measurement instruments
- Leverage: UConn's Center for Manufacturing Simulations, external partners (Federal, industry)

Machine controls & development

- Project features : Complex
- **Unique features of IPB**: Metal testbed (plus infrastructure, such as specialty gas connections), commercial AM machines for development purposes.
- Leverage: Close relation with testbed manufacturer (IPG Photonics) for hardware/software development, enabling follow-up projects.

Equipment

Currently at IPB

- One state-of-the-art Arcam electron beam melting (EBM®) A2X model machines, which is suitable for manufacturing large, complex metal parts at high temperature.
- One EOS laser sintering system (EOSINT M270) for the production of tooling inserts, prototype parts and end products directly in metal
- One wire electrical discharge machining (EDM) machine (Agie Charmilles), which is CNC controlled and can remove parts from the build plate and perform finish machining
- One 3DSystems ProX-300 laser-based metal additive manufacturing machine
- Dedicated powder size- and shape distribution analysis equipment (Camsizer XT), impurity analyzers (LECO ONH 836, CS744).
- Gleeble 3500 with high-temperature mobile conversion unit and HydraWedge mobile conversion unit
- TA Instruments DLF 1600 with 2800 environmental module for thermal diffusivity measurements
- TA Instruments ODP 868 optical dilatometer
- Surface profiler
- High-temperature differential scanning calorimeter
- MRF arc-melter with single-crystal pulling option, gas purification, oxygen monitoring, vaccum casting

Moving to IPB in March 2018

- Furnace rheometer for viscosity measurements of liquid metals and alloys

Connecticut Manufacturing Simulation Center

Mission

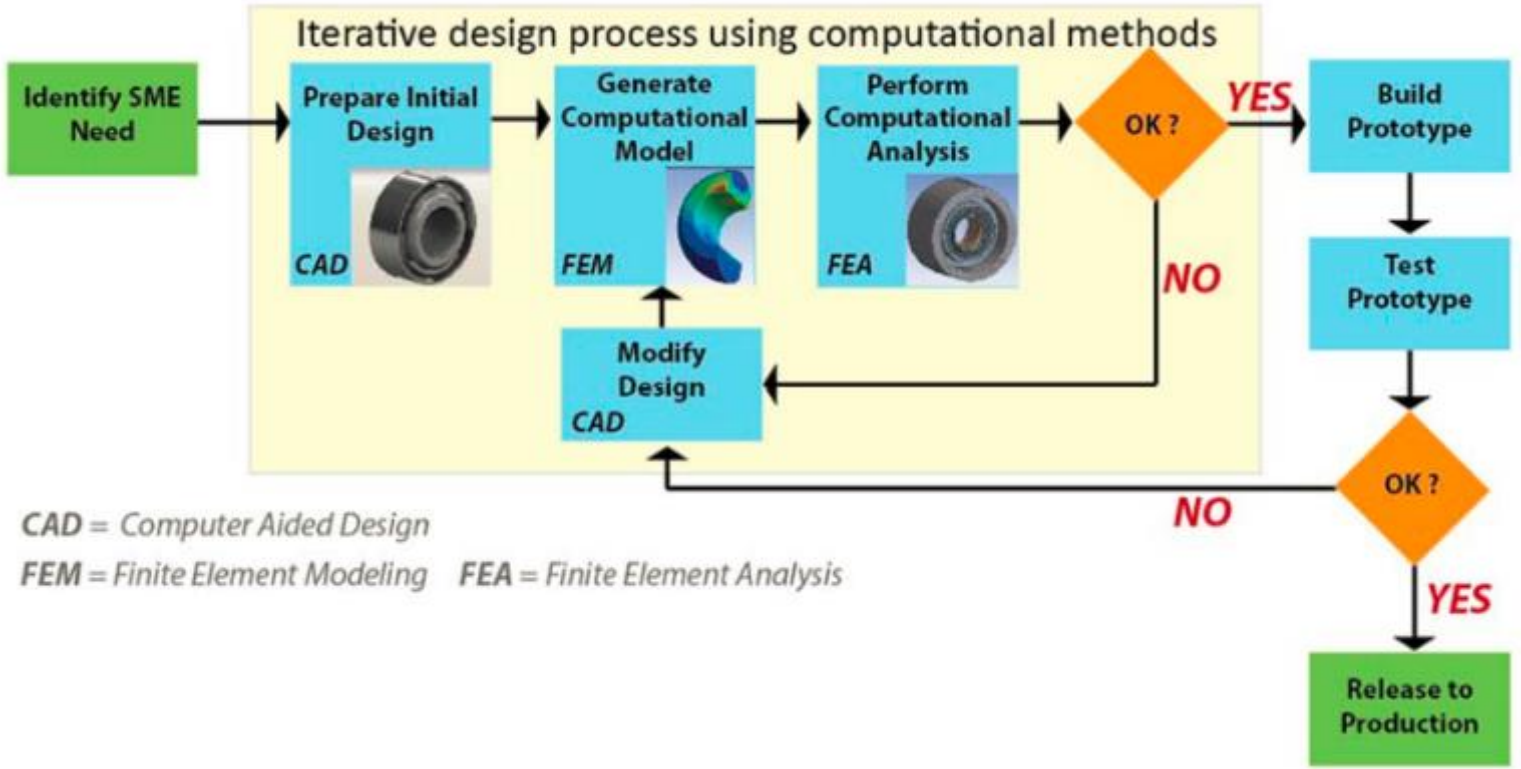
- Enabling small-to-medium enterprises in CT to grow their business by leveraging manufacturing simulation capabilities of UConn.
- Promote innovation and economic development through modeling & simulations
- Develop the next-generation workforce with computing and simulation skills

Services

- Provide finite element technologies to small & medium sized companies
- Offer training program for professionals and student

Benefits to Industry

- Reduced product development cost & time to marke
- Increased productivity
- Improved product quality
- Skilled manufacturing workforce development



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