WASHINGTON STATE UNIVERSITY

Selected Materials Research at WSU

David P. Field
Assoc. Dean for Research and Grad. Studies
Voiland College of Engineering and Architecture
Washington State University, Pullman, WA

Pullman is located about 10 km from the Idaho border…and Moscow, ID (Univ. of Idaho is in Moscow).

We are close to the Snake River and about 20 minutes drive from the West side of the Rocky Mountains.

The population of Pullman is 33 000 and the university student population is about 24 000 in Pullman and 30 000 overall.

WASHINGTON STATE UNIVERSITY

Voiland College

Engineering Degrees are offered at 5 locations across Washington State:

WASHINGTON STATE UNIVERSITY

Voiland College is comprised of 5 Schools, each of which has multiple degree programs:

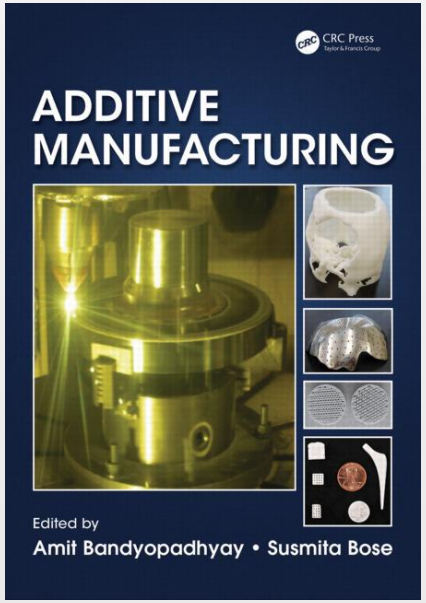
- Chemical Engineering and Bioengineering
- Civil and Environmental Engineering
- Design and Construction
- Electrical Engineering and Computer Science
- Mechanical and Materials Engineering

- In total, 12 undergraduate degrees are offered along with 14 MS degrees and 7 PhD programs

- There are about 4200 undergraduate students and 800 graduate students in the college

Metals Research and Manufacturing

Amit Bandyopadhyay



- **Research Interest** – Additive manufacturing of hard materials

1. Porous metal coating for load-bearing structures
2. Understanding the influence of tribofilms to minimize metal-ion release in Ti-based parts (NSF-GOALI, Zimmer-Biomet Inc.)
3. Minimizing metal-ion release in CoCrMo alloys (LSDF, WA)
4. Silver based antimicrobial coatings on Ti (Nanovation Partners)
5. Additive Manufacturing of Porous Ta coating (H. C. Starck, MA)

Materials for space related programs -

1. Micro-porous filters and high temperature coatings (JCATI, WA and Aerojet-Rocketdyne, WA)
2. High temperature ceramics and metal-ceramic composites (SpaceX, CA)
3. Additive manufacturing of bimetallic structures using Inconel 625 (Coming - NASA-Marshall, AL)

Teaching Interest – Materials Science, Manufacturing

- Fall 2015 - ME 579 / MSE 503 – Additive Manufacturing

Additive Manufacturing of Multi-materials

Amit Bandyopadhyay (MSE) and Susmita Bose (MSE)
working with Aerojet-Rocketdyne and others

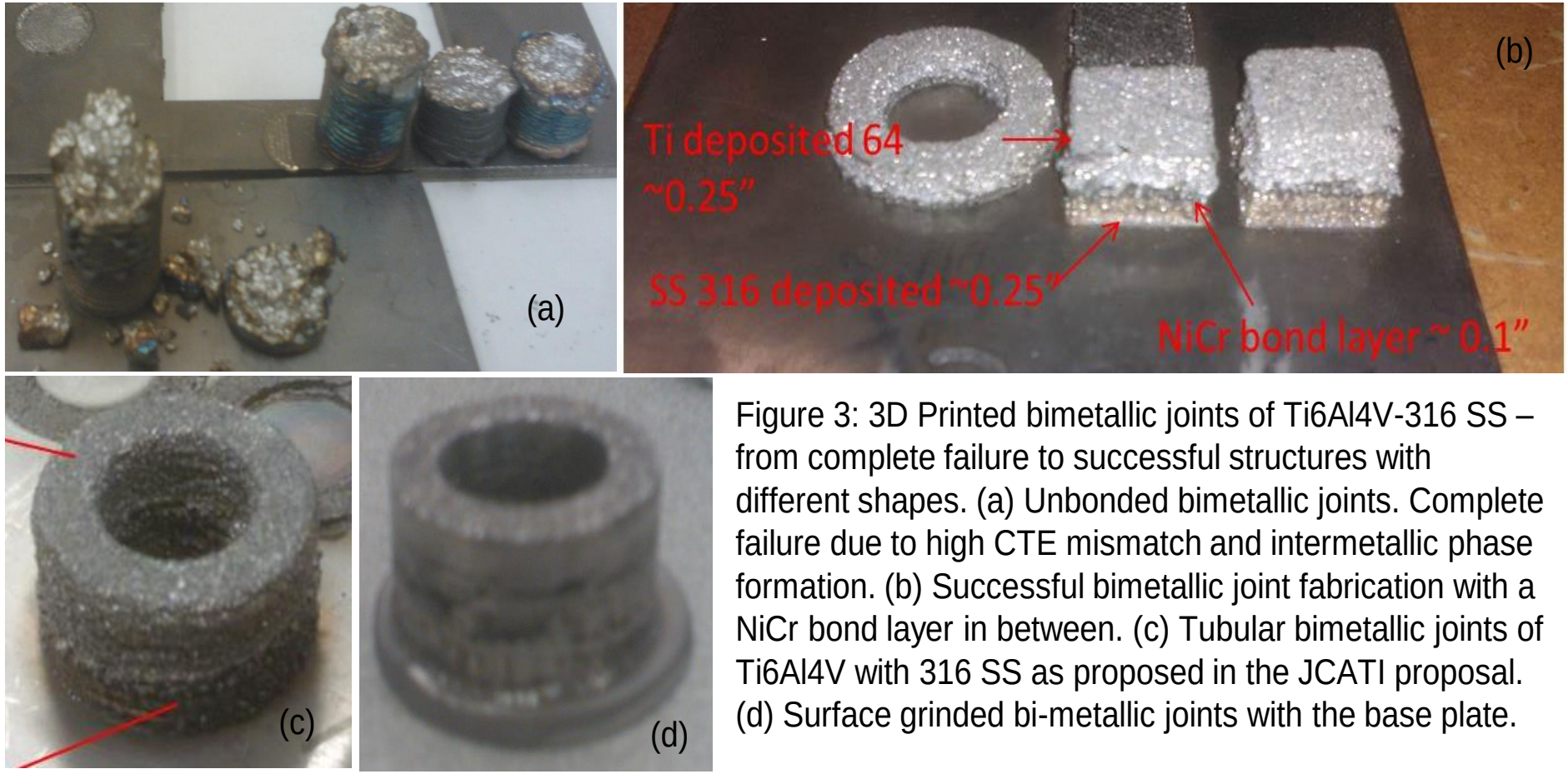
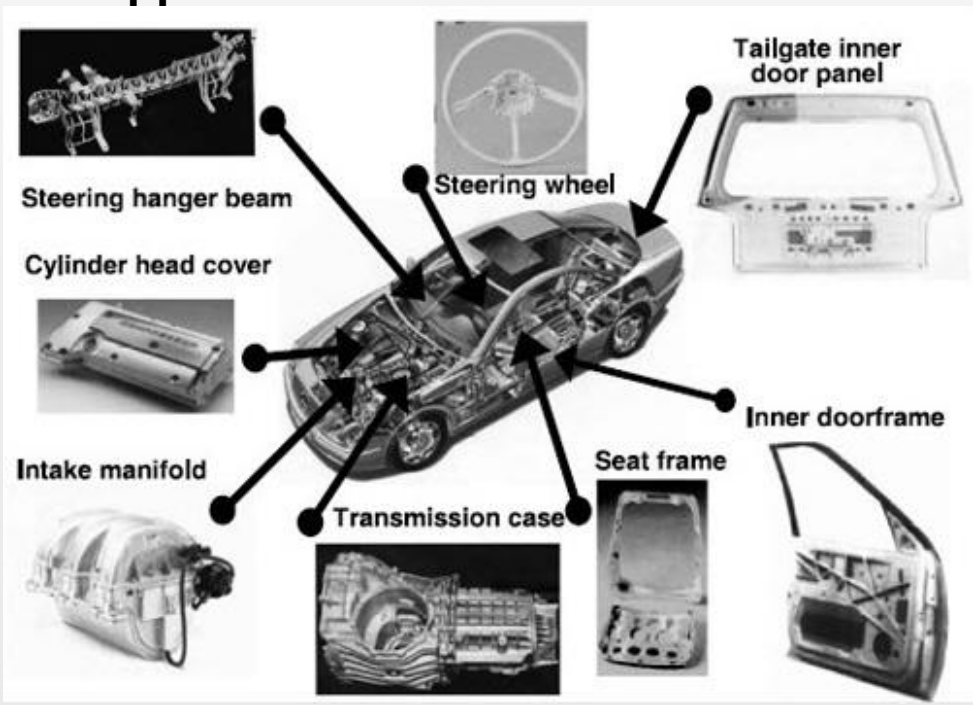


Figure 3: 3D Printed bimetallic joints of Ti6Al4V-316 SS – from complete failure to successful structures with different shapes. (a) Unbonded bimetallic joints. Complete failure due to high CTE mismatch and intermetallic phase formation. (b) Successful bimetallic joint fabrication with a NiCr bond layer in between. (c) Tubular bimetallic joints of Ti6Al4V with 316 SS as proposed in the JCATI proposal. (d) Surface grinded bi-metallic joints with the base plate.

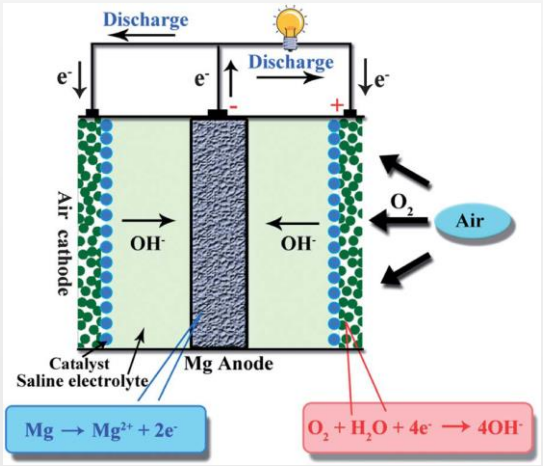
Qizhen (Katherine) Li

- Light weight metals, metal-based composites, shape memory alloys, nanostructured materials for structural, transportation, energy, and bio applications
- Synthesis, processing, microstructure characterization, mechanical testing

Structural applications

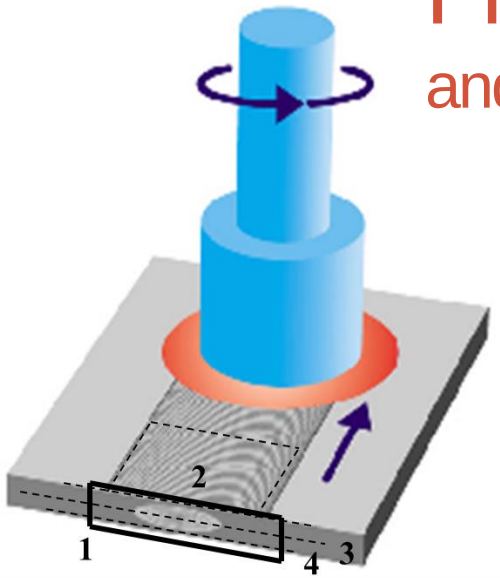


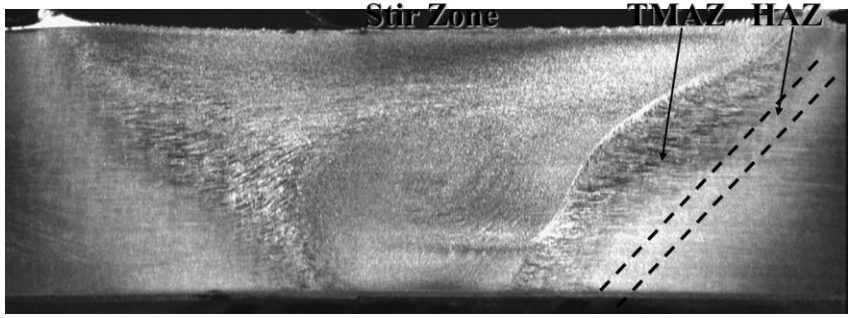
Energy application



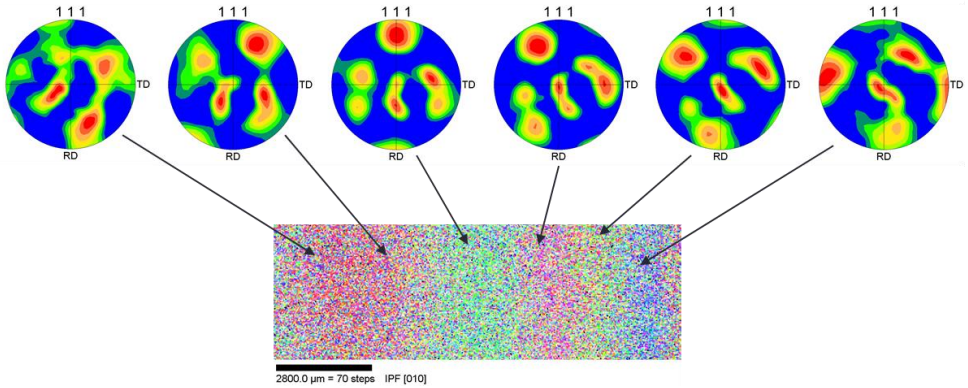
Friction Stir Welding of Light Metals

and multi-materials

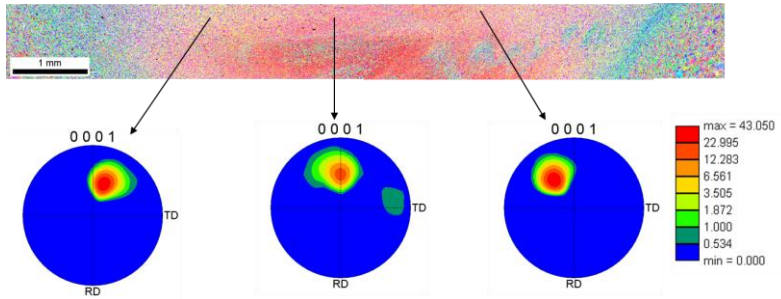


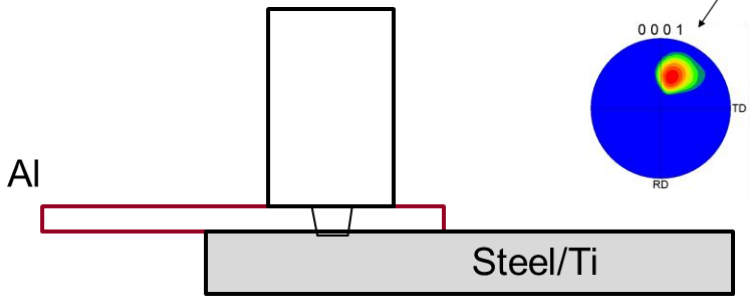


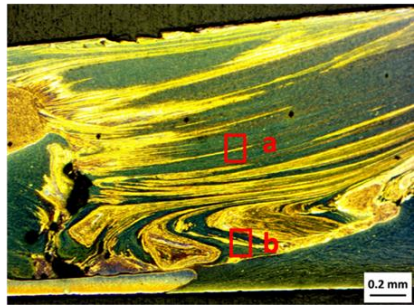
7050 Al



Ti 6Al 4V







Taylor Factor in Al FSW – Dark areas are relatively weaker than the light regions for the loading condition shown.

Hussein M Zbib

Computational Mechanics and Materials Science (cmms.wsu.edu)

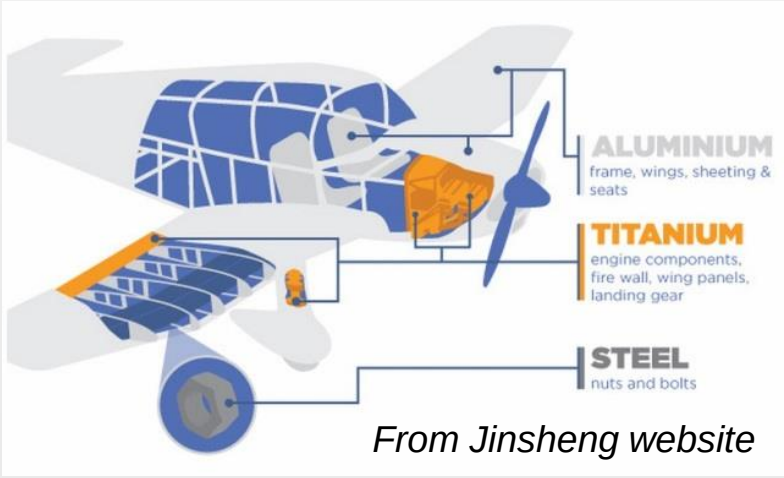
Thermo-mechanical behavior of solids:

Solve engineering and scientific phenomena spanning the length scale and occurring under extreme loading and environmental conditions, with emphasis on deformation, damage, fracture and material instabilities.

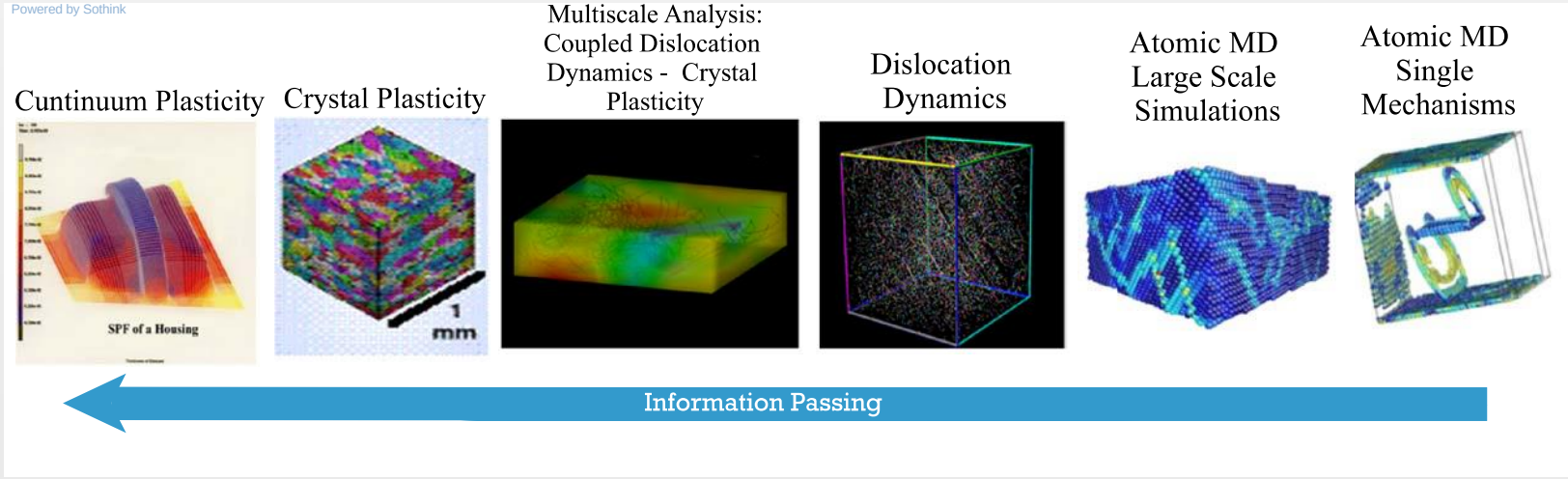
Develop multiscale models that are based on first principle calculations and link scales through information- passing

-Nanometer to micrometer: Investigate the mechanical performance of metals and composites with emphasize on nanolaminate metallic/ceramic structures, composites and thin films.

-Micrometer to macrometer: Investigate the behavior of metals and geological materials under extreme conditions: shockwaves, metal forming, high speed machining, superplastic forming, etc.



From Jinsheng website



Ceramics and Electronic Materials

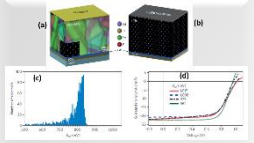
WASHINGTON STATE UNIVERSITY

World Class. Face to Face.

Center for Materials Research

CMR is an interdisciplinary group of faculty members from nine different academic departments who collaborate on cutting edge research in materials science. Consolidating financial and intellectual resources provides the benefits of attracting larger grants, gaining access to technologically advanced equipment, and bringing other internationally recognized faculty and promising graduate students to the group.

Thin Film Solar Cells



Thin film solar cells have leaped ahead of bulk silicon in efficiencies. Figure (a) and (b) represent CdTe solar cell structure and occupation of lattice sites by dopants. (c) Indicates a histogram of open-circuit voltage (Voc) for more than 2400 cells fabricated at NREL. (d) J-V curve of the world record cell that broke the historic 1 Volt barrier, using WSU CdTe:P crystals. Further improvement of CdTe solar cell efficiencies can be achieved by improving the open-circuit voltage which requires increasing the net acceptor density and carrier lifetime in the CdTe absorber. CMR is developing heavily doped feedstock by controlling purity and stoichiometry in a cost effective production process that will carry over to industry.

CdZnTe

Cadmium Zinc Telluride can be grown for use as a solid state x and gamma ray detector that operates at room temperature. Our research involves growing and characterizing the unique properties required to fabricate a fully active detector. Crystal growth of CdZnTe causes native defects and must be compensated to produce a fully active detector. Because of these defects, reproducibility and high quality yields are low. Recent results show that with compensation, high purity and large single crystals, fully active detectors with high yields are achievable and reproducible.

Positron Spectroscopy

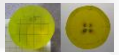
Ongoing research in antimatter annihilation is being carried out in CMR's positron lab. Companies like Boeing, Intel, and others obtain vital information to material structures, vacancies, inclusions, and defects. This is a unique, high-level material analysis method.

CMR Director

Dr. Kelvin Lynn was hired as the Center Director in 1996. Previously he had been a Brookhaven physicist for 23 years and had become world-renowned for his research in positron annihilation. Dr. Lynn holds the WSU Boeing Chair in Advanced Materials Science and is a Fellow of the American Physical Society.

Czochralski Crystals

Over the years, CMR has grown many types of single crystal ceramics including ruby, sapphire, Ga_2O_3, $LiAlO_2$, YAG, and others. Industry growers do not have the luxury of experimenting with dopants or co-dopants as every crystal must yield a profit. CMR's single crystal growing



Cleanroom

CMR operates a cleanroom that is located in the Engineering and Teaching Research Laboratory building. The cleanroom is a microfabrication lab that is available to industry and academic entities alike for research, technology and process development, and prototyping projects. It is approximately 1100sq.ft. and complies with Class 1000 standards. The cleanroom

CMR Funding

Provided by:

National Science Foundation

NSA

Homeland Security

Pacific Northwest National Laboratory

SMDC

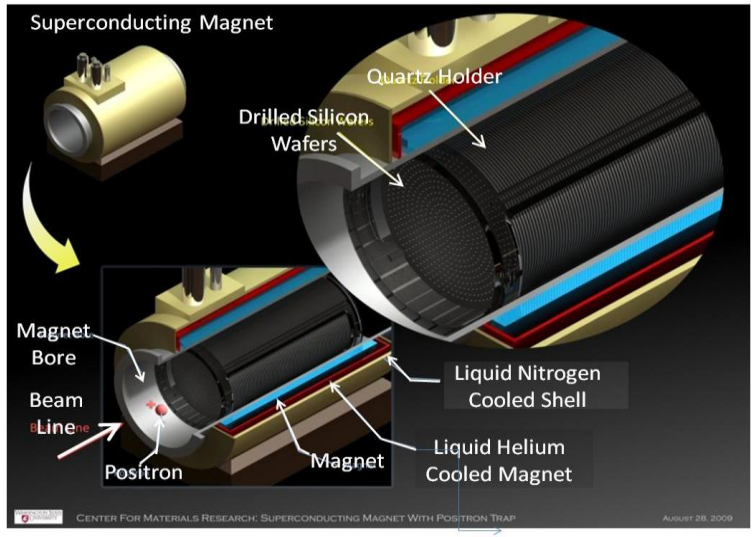
Lawrence Livermore National Laboratory

SRNL Savannah River National Laboratory

Email: cmr@wsu.edu Telephone: (509) 335-1131 Fax: (509) 335-4145 Web: www.cmr.wsu.edu
Center for Materials Research, Dana 102, PO Box 642711, Washington State University, Pullman, WA, 99164-2711

Detectors, Positrons, Crystal Growth

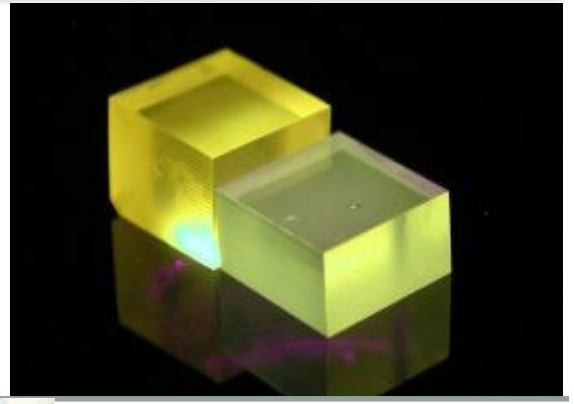
Kelvin Lynn and Marc Weber (ME and Physics) working with II-VI and others

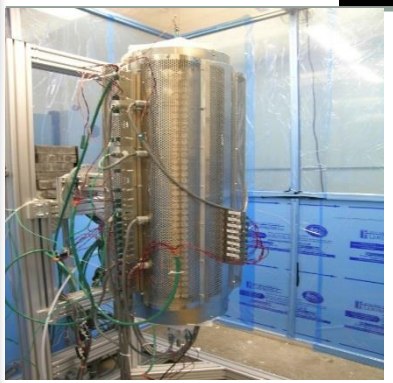


Conceptual design Cryogen Antimatter Storage Container for deep space propulsion (5 cm diameter of trap array)[Lynn/Weber/WSU Patent]

- Growth and Characterization of radiation detectors and photovoltaics
- Use of positrons for spectroscopy and defect profiling

Direct optical excitation of Ce^{3+} ions in Ce:YAG crystal →





One of 3 EDG Vertical Bridgman furnaces

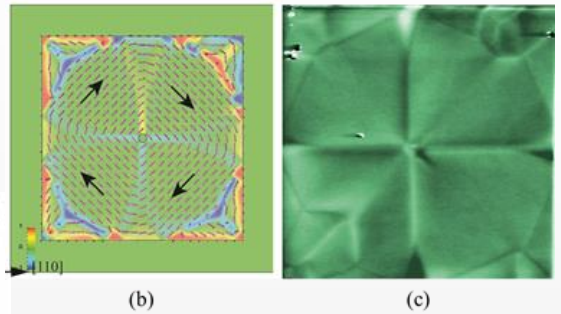
RESEARCH FACILITIES

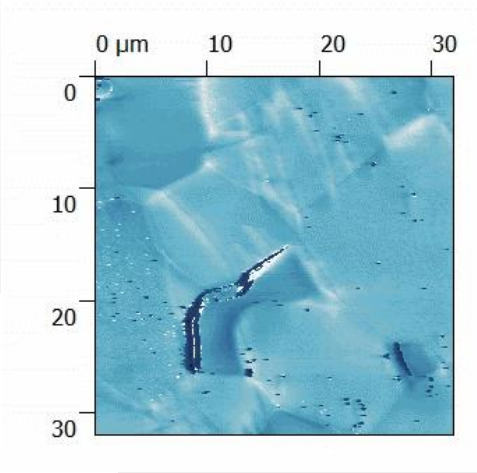
- Keck Antimatter Lab
- Semiconductor Lab
- Thermal Fluids Lab
- Crystal Growth Lab
- Positron Lab
- Two Clean Rooms

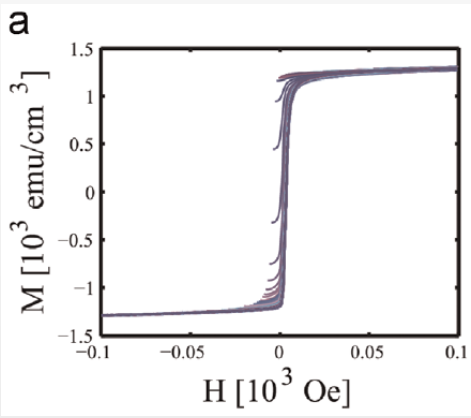
John McCloy

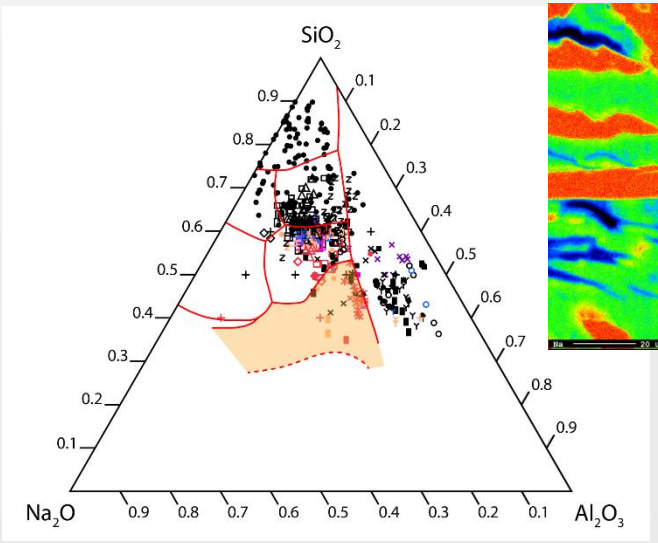
Nuclear, Optical, Magnetic, & Electronic (NOME) Materials Lab

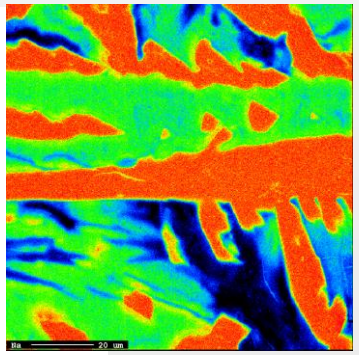
- ***Magnetic materials and properties***
- ***Nuclear waste forms***
- ***Advanced material characterization***
- Radiation effects on materials
- Optical ceramics and glasses
- Electronic transport
- Sensors

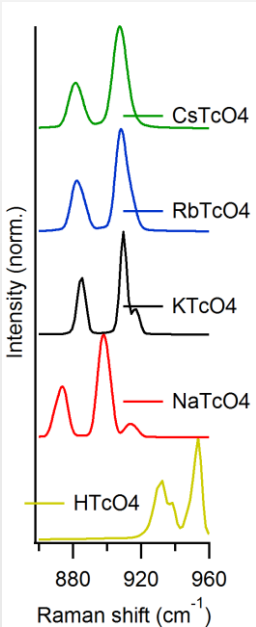


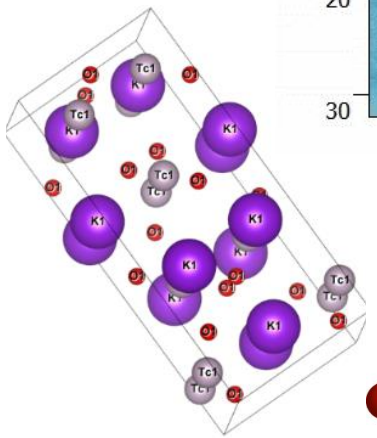


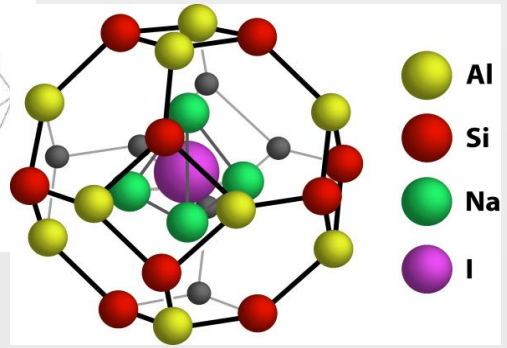












http://labs.wsu.edu/mccloy/

Batteries, Fuel Cells, Energy Systems

Min-Kyu Song

- Materials Design and Sustainable Technology

(1) Carbon-Inorganic Hybrid Materials for Energy and Environment

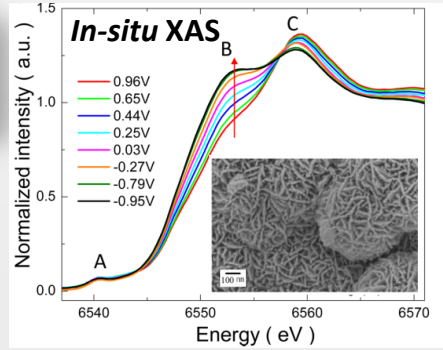
(2) Next-Generation Energy Storage Systems: Beyond Li-ion Batteries

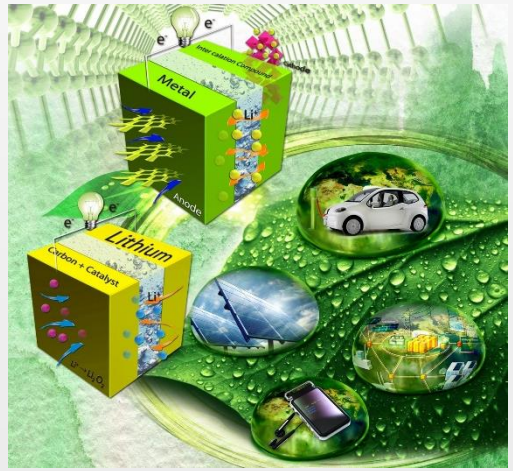
(3) Novel Membranes and Catalysts for Advanced Fuel Cells

(4) Nanoporous Materials for Electrochemical Desalination

Materials Design and Synthesis
(Defects, Composition, Morphology, Size)

Advanced Materials for Sustainable Energy





Fabrication of Functional Devices
(Batteries, Fuel Cells, Solar Fuels Generators)

Advanced Characterization
(Electrochemistry, Spectroscopy, Microscopy)

Soumik Banerjee

Modeling materials relevant to energy conversion and storage devices

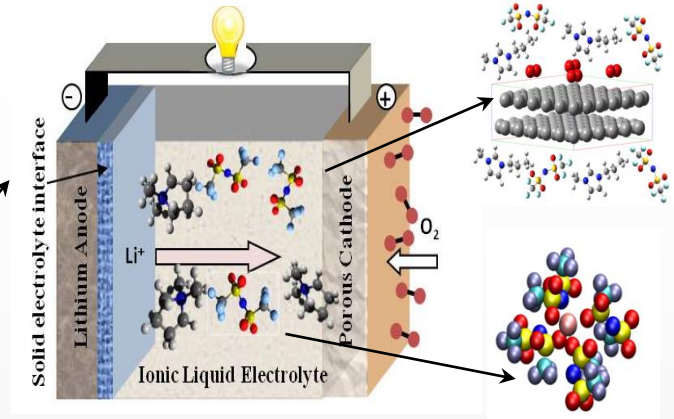
For more information, please visit:
http://www.mme.wsu.edu/~sbanerjee/

Contact information:
soumik.banerjee@wsu.edu
Office: 215 Sloan Hall

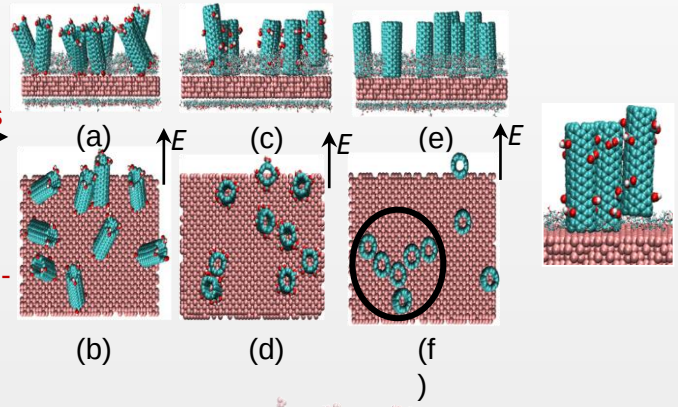
Research Interests

- Nanoscale transport phenomena
- Molecular modeling of materials
- Organic photovoltaic solar cells
- Electrolytes in Li batteries

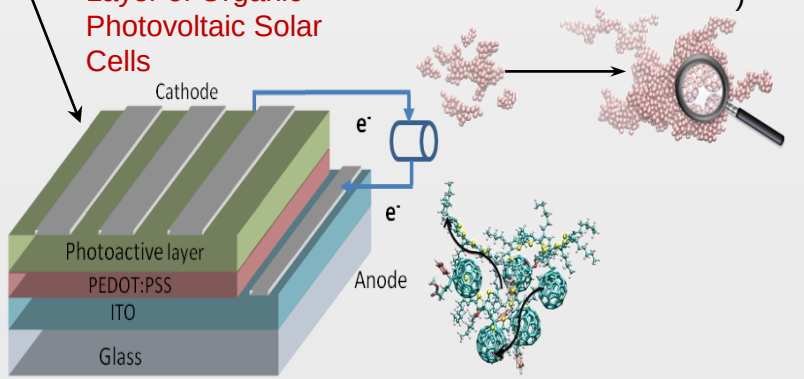
Identifying Novel Electrolytes for Lithium Batteries



Controlled Deposition of Aligned Carbon Nanotubes on Substrates for Super-capacitors



Modeling Solution-based Fabrication of Photoactive Layer of Organic Photovoltaic Solar Cells



A Gummy Electrolyte with Damage-tolerance and Thermal-protection Capabilities for Safer Li-ion Batteries (LIBs)

Prof. Katie Zhong, Washington State University

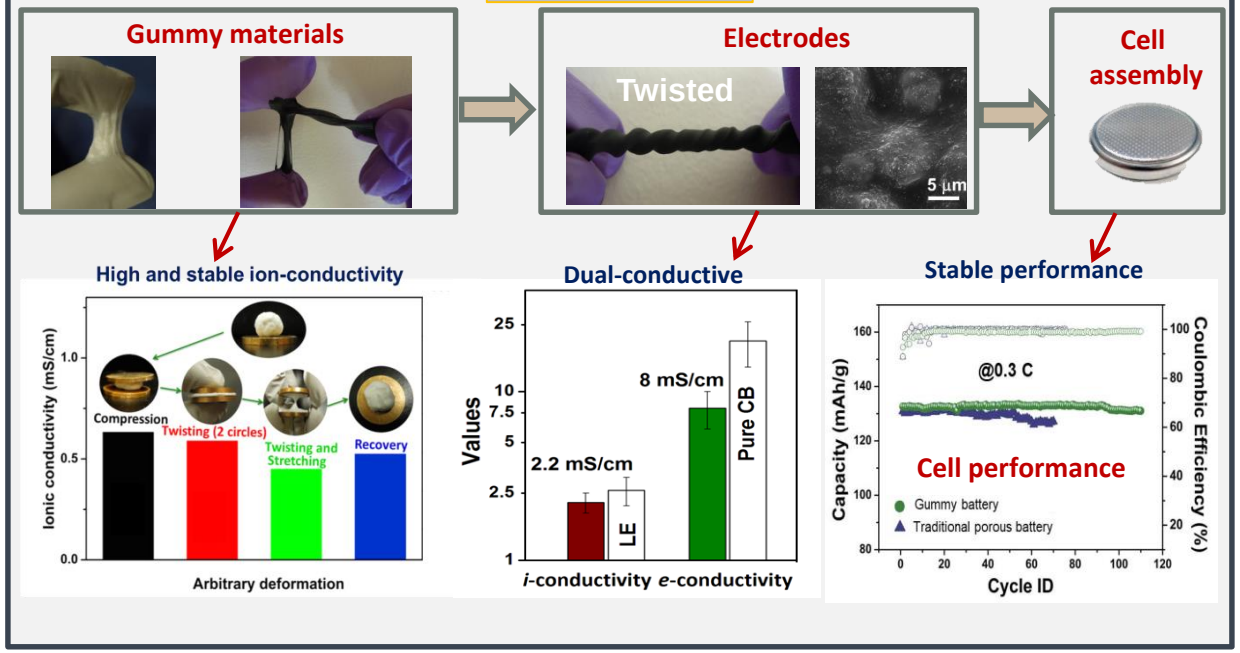
Objective

Safety issues

Challenges: trade-off between Safety and performance

Our solution:
Non-liquids: Adhesive battery materials →

Key Results



Performance

- **Safety design: thermal protection**
- **High conductivity: liquid level**
- **Good mechanical properties: solid level**
- **Excellent adhesion w/ electrodes**

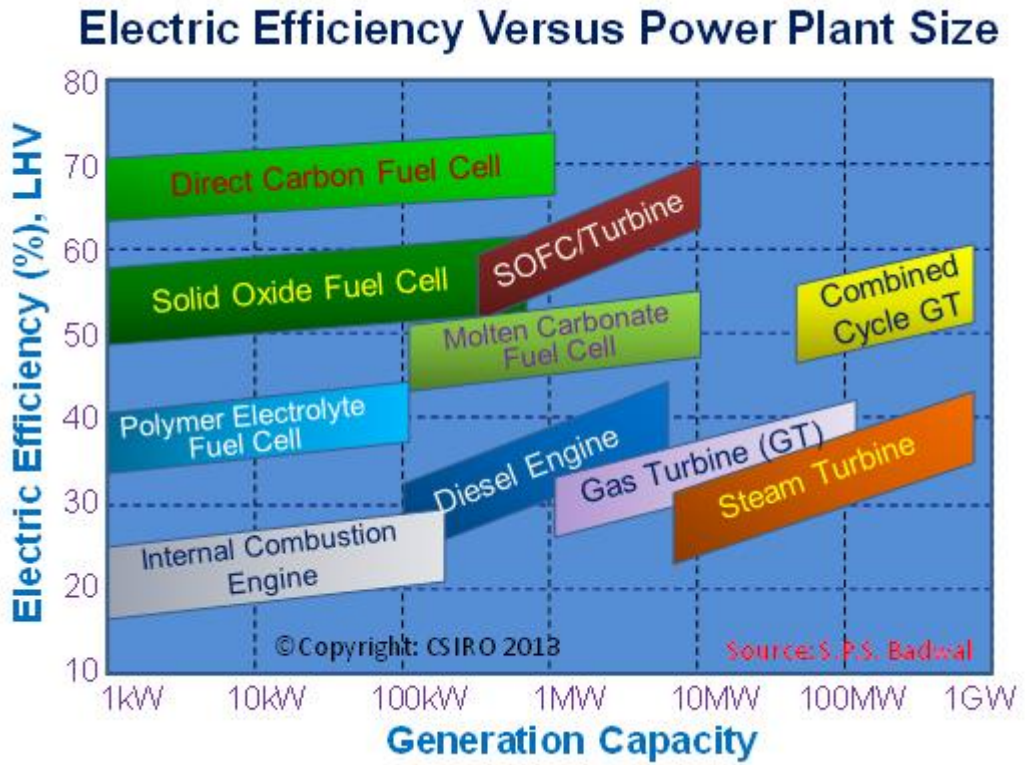
Impact

On Boeing: Safe and advanced airplane LIBs

On Microsoft: Safe battery materials for personal electronics

Fuel Cell Technology: Advantages

Profs. Su Ha (Chemical Eng) and Grant Norton (MSE)



Fuel Cell Technology

(1)Generates electricity more efficiently than gas turbines

- **Fuel Cell: Between 35 to 70%**
- **Gas Turbines: Between 25 to 40%**

(2) Allows a significant fuel saving

(3) Has no moving parts

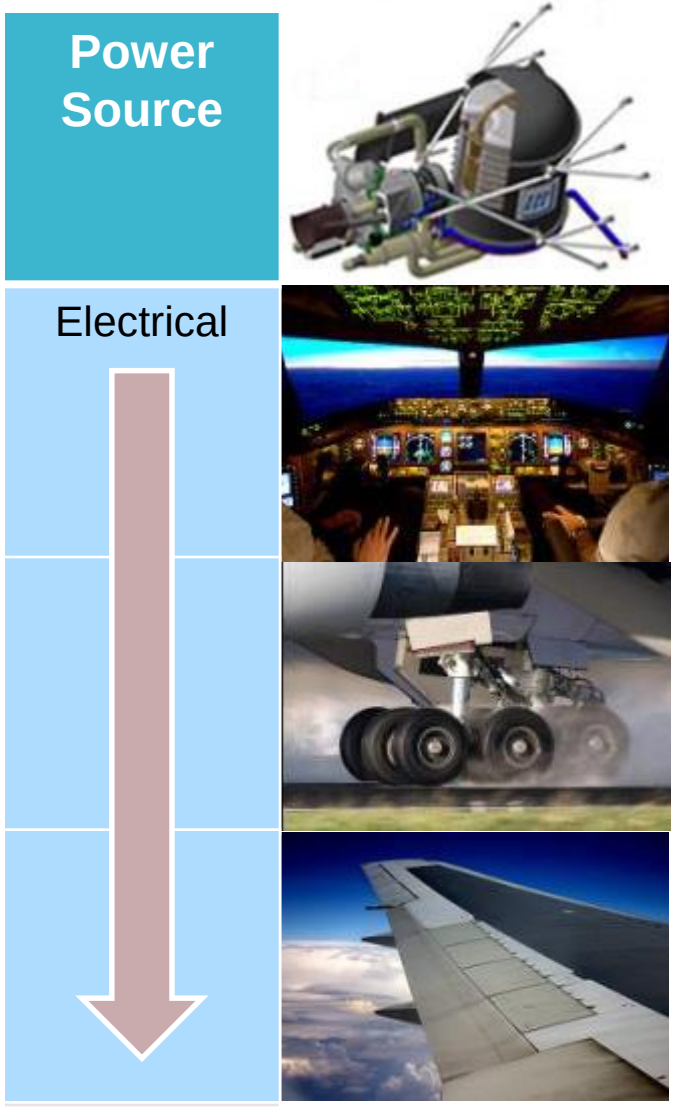
- **Reduce maintenance costs**
- **Reduce acoustic signature**
- **Reduced emissions**

Enables to meet the electrical power needs of future airplane designs

More Electric Airplane (MEA) Background

- Efficiency changes in 787 due to:
  - Composite airframe
  - Efficient no-bleed engines
- Transition in power sources in the MEA
  - Increase in electric power to ~1.5 MW

Efficient No-Bleed Engines



Prof. Yuehe Lin's Group

Electrochemical Storage for Airport Power Back-Up

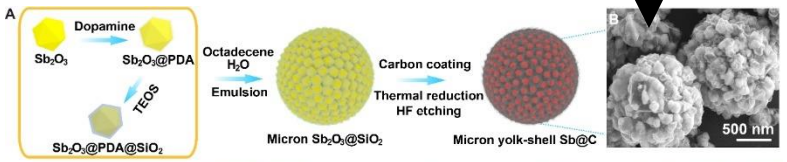
To increase energy *sustainability* and *efficiency* using earth abundant materials: salt, carbon and iron.

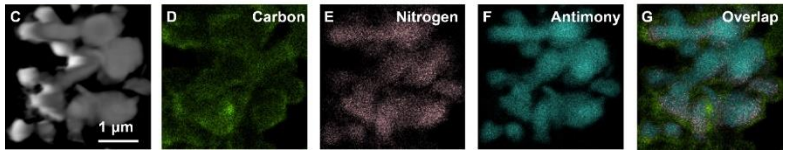
Na-ion Batteries

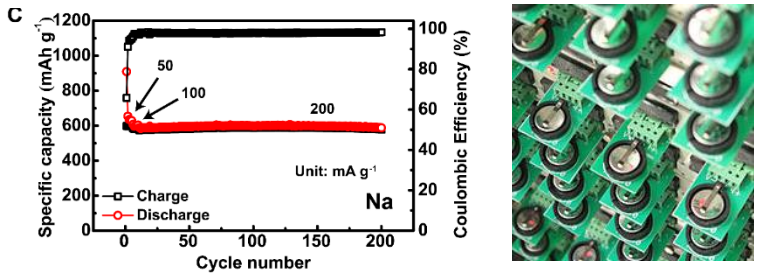
Sea salt

+

Advanced alloy

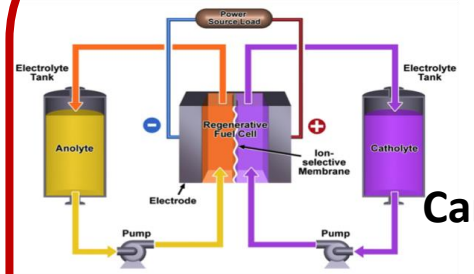




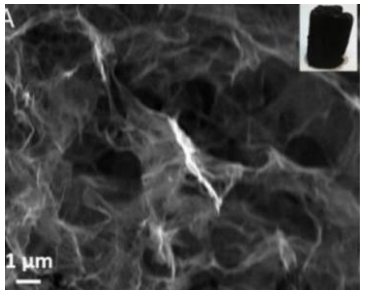


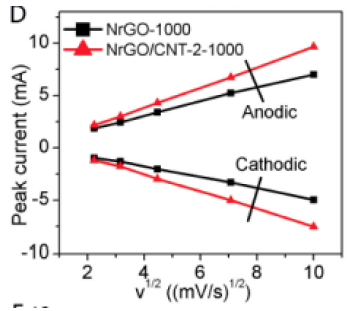
Low Cost Li-ion Alternative

Flow Batteries



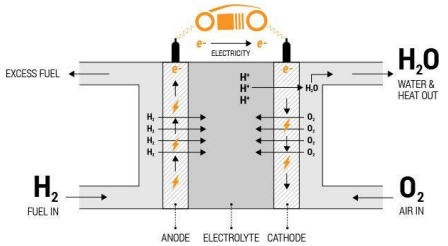
Engineered Carbon electrode



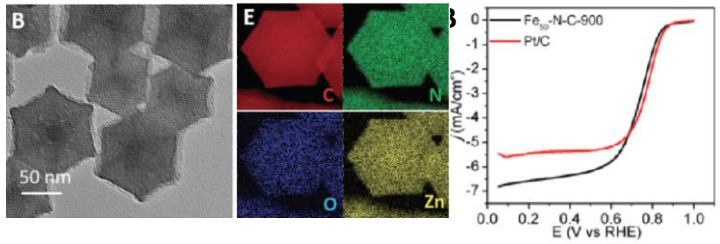


Power Back-up

Fuel Cells



Low cost Iron-based catalyst



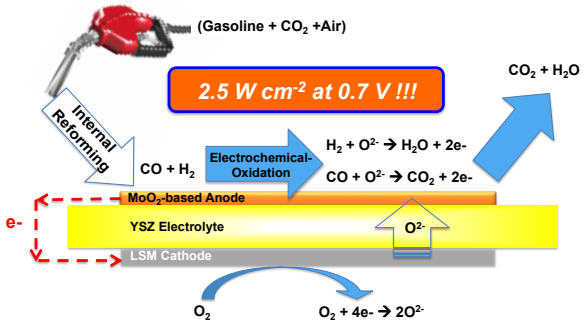
Clean Utility Vehicle

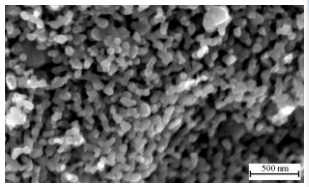
M. Grant Norton

Nanomaterials for Energy and Medicine

Direct Liquid Fed Fuel Cells

Kale Harrison
Qian He

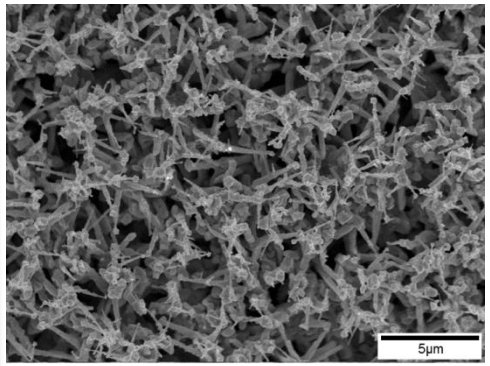


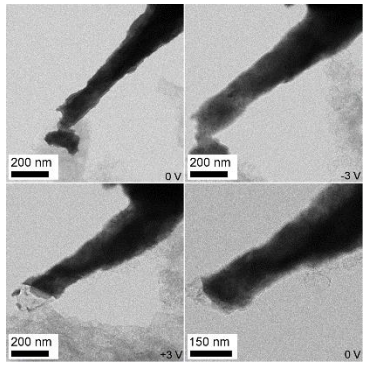


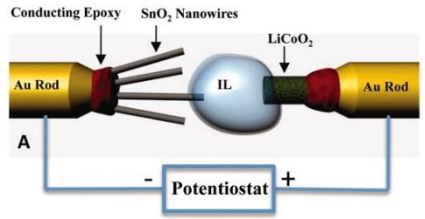
Enabling material: Nanoparticle MoO_2

Next Generation Batteries

David Mackay
Craig Owen



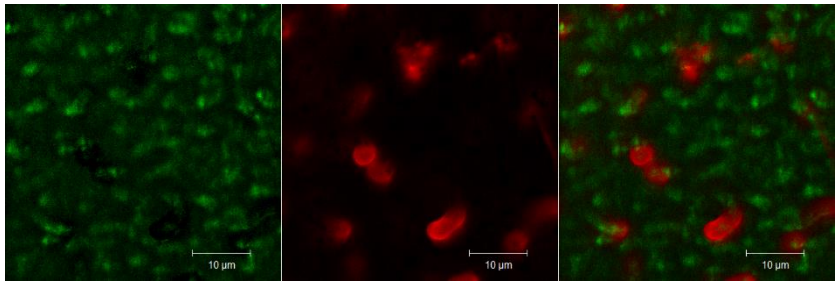




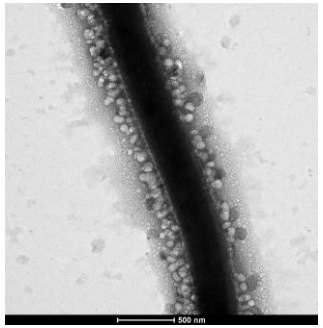
Tin anodes for Li-, Na-, Mg-ion batteries

Exosome Capture

Parissa Ziaei



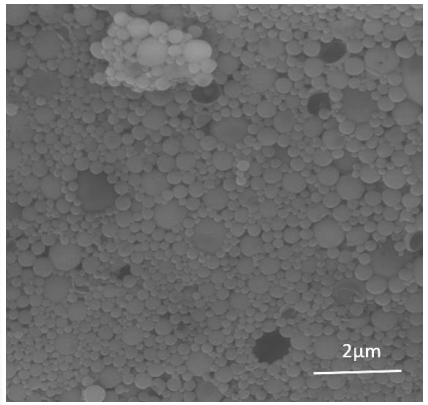
Confocal Image: capture 22RV1 exosomes

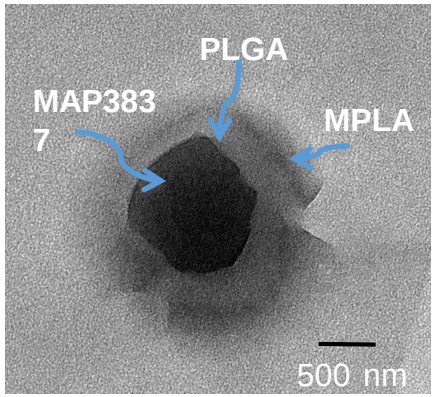


TEM image of captured exosomes

Nanoparticle-based Vaccines

Parissa Ziaei





Nanoparticle PLGA

MAP 3837 – vaccine for bovine tuberculosis
MPLA – targeting ligand

WSU The College of Veterinary Medicine

Polymers, Composites, Adhesives

Composite Materials Engineering Center

Don Bender, Director (CE and MSE), J. Zhang, K. Zhong, M. Wolcott, V. Yadama, K. Englund, etc.

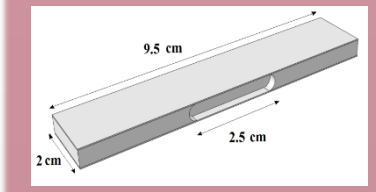
- Assisted numerous start-up ventures in composites.
- Metriguard - leading producer of NDE equipment
- By-Product Synergy NW

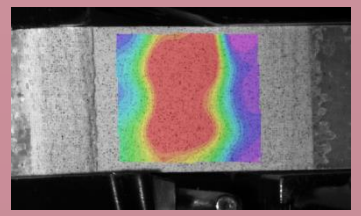
Value for Industry

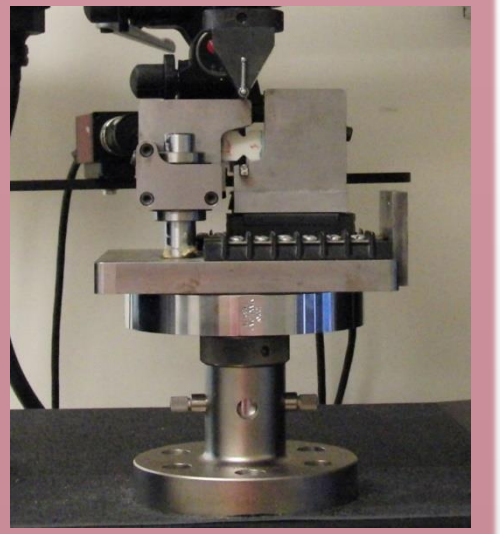
- Solve technical and product hurdles
- Improve/expand product offerings
- Improve manufacturing processes
- Partner on government grants (SBIR, USDA, Navy)
- Exposure and access to faculty and IP

Lloyd Smith

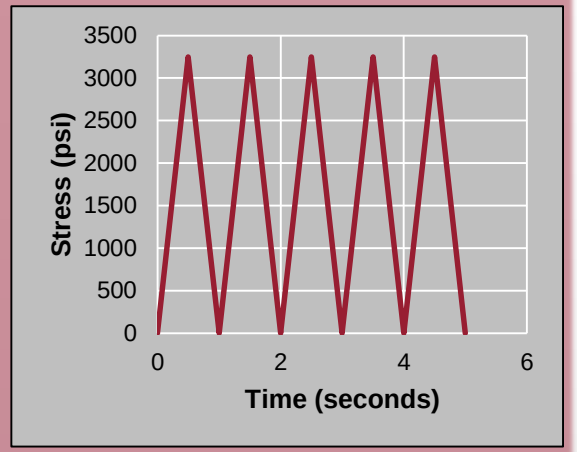
Composite Damage

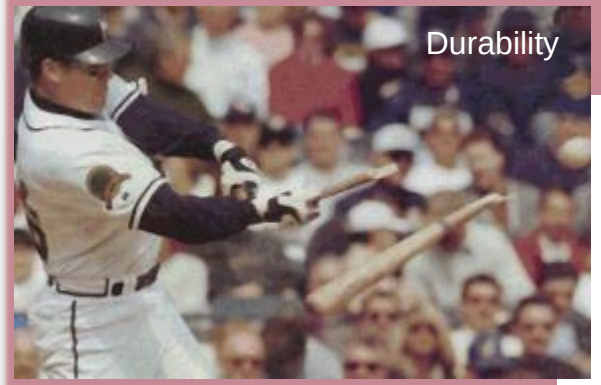




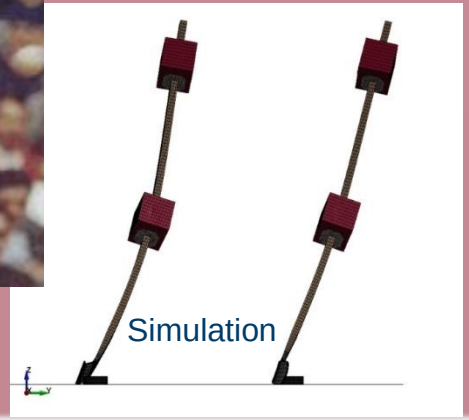


Composite Adhesion





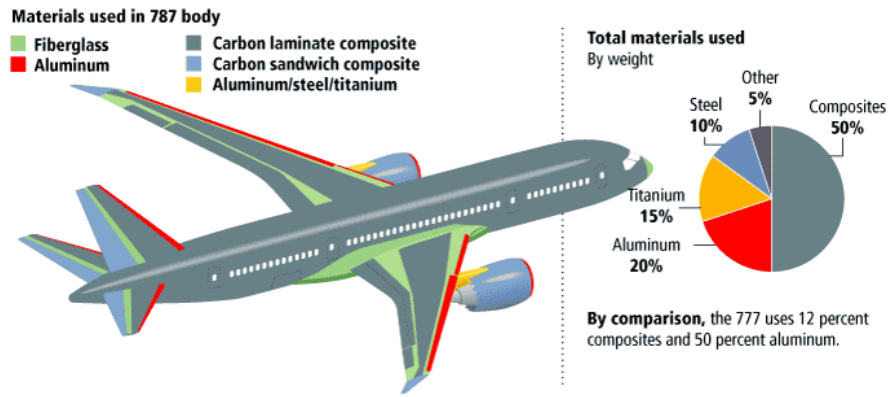
Sport

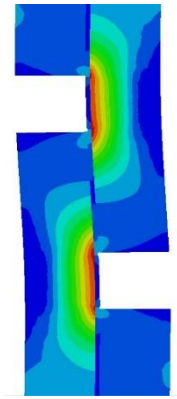


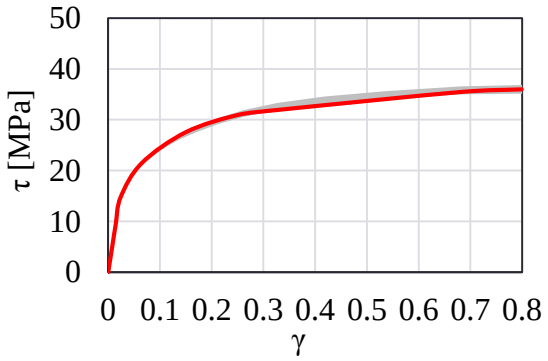
Adhesive Characterization

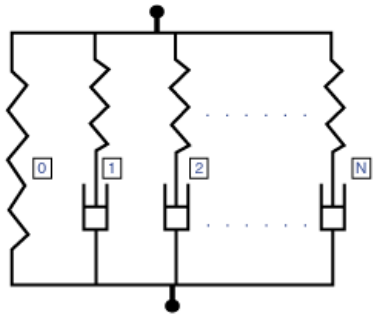
Lloyd Smith (sponsors: FAA & Boeing)

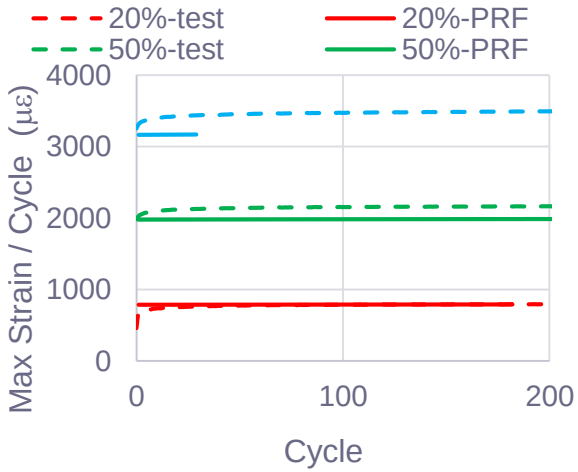
- Adhesive bonding is increasing with modern aircraft
  - Adhesive response under high load is not well understood
- Project aims
  - Develop plasticity models for toughened adhesives
  - Consider viscoelastic effects from cyclic loading











W. H. Katie Zhong

- **Structural composites**: matrix materials, interface issues, nano-nectar ("liquid nano-reinforcement") for matrices;

  Support : NASA , The Spirit Aerosystems Co. , and NSF

- **Functional nanocomposites**: Electrical, dielectric, etc, industry applicable processing & quality assessment tools:

  Support: Boeing Co, Sabic-IP Co. and NSF

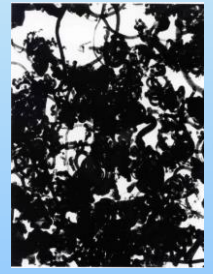
- **Advanced battery materials**: promoting safety of LIBs and for next generation batteries

  Support (2012-present): IV Co., WSU, USDA and NSF

- **Bio-air filtering Materials**: Bio-based multifunctional air filtering materials and processing

"Nano-nectar" Technology for Reduced-cost Manufacturing of Structural Composites

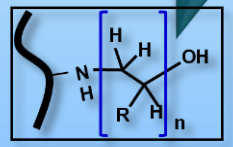
Lab work: Nano-nectar



(Diluent)

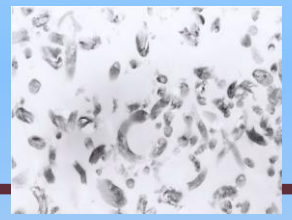
BGE (Liquid)

Reactive Fibers



Nano Nectar:"Liquid Nano-Reinforcement" (LNR)

(Reactive Fibers/BGE)



Industry: Nano-nectar+ Epoxy

Manufacturing Advantages

High quality:

Very uniform;

Extremely stable ;

Easily handling:

Simply stirring

Nano-epoxy

Performance Advantages

Mechanical performance

Thermal stability

Wettability

Viscosity

Properties of Nano-epoxy Matrix

Prof. Katie Zhong (MSE)

- lower nanofiber loadings (e.g. 0.3 wt % r-GNFs)

- not a simple mixture or common nanocomposite

- **Enhanced mechanical properties:**
  - **Flexural strength ↑ >25%, modulus ↑ > 20% and breaking strain ↑ >30%**
  - **Fracture toughness ↑ >35%**
- **Increased thermal properties:**
  - **Higher Tg ↑ 15 ℃, lower CTE value**
- **Relaxation behavior:**
  - **Better dimensional stability**
- **Viscosity:**
  - **Lower viscosity ↓ 52%**
- **Chemorheological properties:**
  - **Longer gelation time at lower viscosity level**
  - **without increasing activation energy**

✓ Good for Resin Infusion Technology for Manufacturing Fiber Composites

Textile and Material Research/Testing Center

Dr. Hang Liu
(Apparel, Merchandising, Design and Textiles; Composite Materials and Engineering Center)

Equipment

- More than 20 pieces of textile physical and mechanical property testing equipment

Research

- Hemp fiber reinforced composite
- Smart Textiles for Airplane Interior:
  - Stain-Resistant and Energy Saving Textiles
- Recycle Interior Textiles

Value for Industry

- Develop innovative textile materials for airplane interior and composites for both interior and exterior
- Partner on government grants
- Testing on Textile Material Performance

Weather-ometer


Universal Material Tester

Vertical Flammability

Lightweight Polymer Composites and Mild Chemical Recycling of CFRP

Prof. Jinwen Zhang

Collaborations with Global fiberglass Solutions, Inc and Ultra Polymers (JCATI), Jiangsu Citic New Century Materials

Lightweight Composites

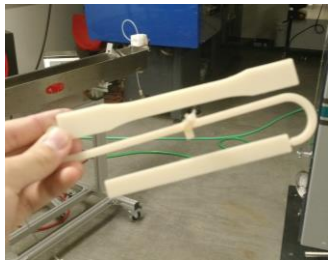
- Compounding of thermoplastic engineering polymer with hollow glass microsphere (HGM);
- Modifications of interfacial adhesion, toughness and flame retardancy

Nylon

Treated HGM

Compounding

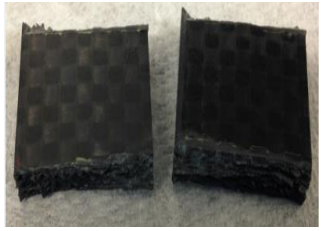
Additives



Lightweight composite

CFRP recycling

- Mild chemical degradation of the matrix polymer in an aqueous medium
- The reaction medium with catalyst are conveniently recycled and reused
- Without separation, the degraded polymer and recovered fiber are directly used for new composites

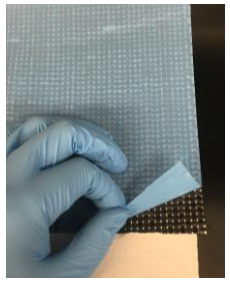


CFRP waste

Mild reaction conditions

Recycled fiber

Degraded polymer



Prepreg waste

Precut, Compounding

New composite

Recycling of Aerospace CFRP Composites

Recycling Carbon Fiber Composites

Karl Englund, Somayeh Nassiri, Kun Zhang (CE)
Collaborations with Triumph Composites (JCATI), Boeing Co. and Global fiberglass Solutions, Inc

- CFCs
  - Industries
    - Aerospace, energy, auto, etc…
    - Increasing %'s in all areas
  - 2nd use
    - No option for manufacturers
    - Technology gap

Thermoplastic CFCs

Refined molded

Recycled composite

- Recycling Concept
  - Minimal energy used
  - Retain composite integrity
  - Methods
    - Compression mold elements into a new composite
    - Pavement design

Thermoset CFCs

Refined Fractionated

Used to reinforce pervious pavements

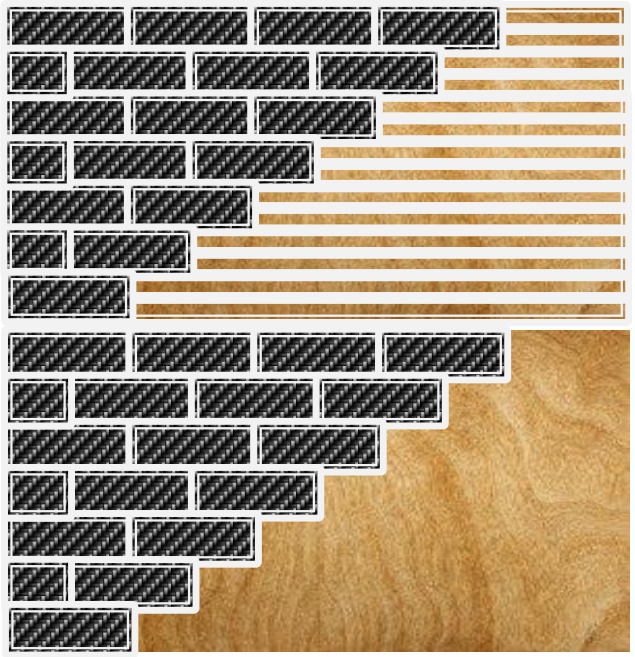
Can we utilize high-performance composites waste streams from aerospace industry to develop hybrid wood composites?

V. Yadama, Hang Liu, and Lloyd Smith

- For use in building structures?
  - *Hybrid cross-laminated timber to improve stiffness*
  - *CLT Floors -- often spans are limited by deflection*

Cross Laminated Timber

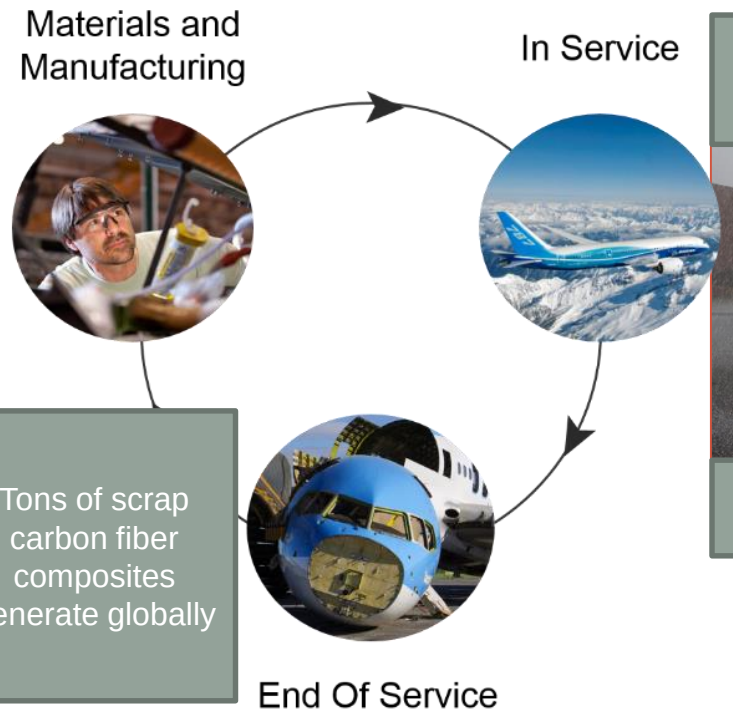
- For use in automotive manufacturing?



RTM/VARTM of Automotive Parts

Discrete reinforcement from cured carbon fiber composites as reinforcement for permeable pavements

Karl Englund (CMEC), Somayeh Nassiri (CEE) & Kun Zhang (CEE)



Tons of scrap carbon fiber composites generate globally

www.khq.com

Permeable pavements reduce stormwater runoff
Make roads safer by reducing wet weather accidents
Filter stormwater & remove pollutants

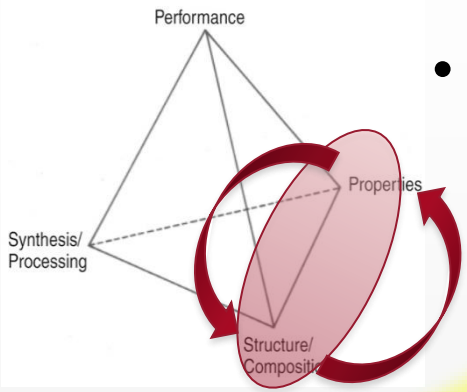
However, the voided structure result in reduced strength & durability

evolutionpervious.com/problem-prevention-services

Resized carbon fiber composites as discrete reinforcement add to strength & durability of permeable concrete & asphalt

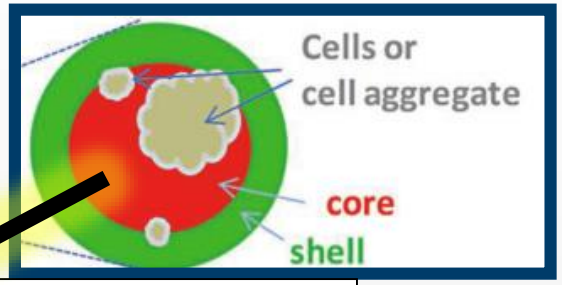
Computational Materials Research

Scott P. Beckman



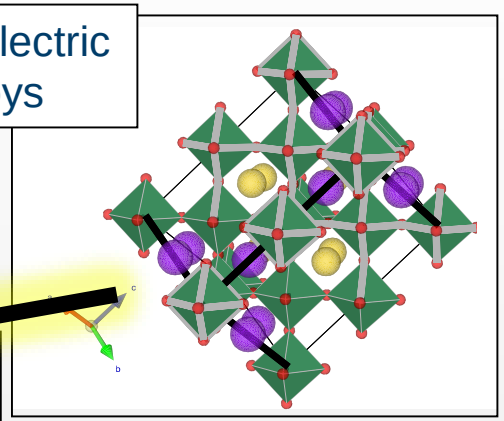
Theoretical materials science

- Specialization: Electronic structure calculations

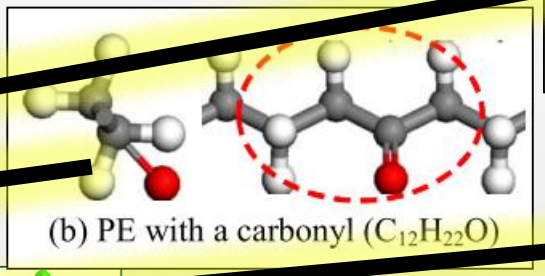


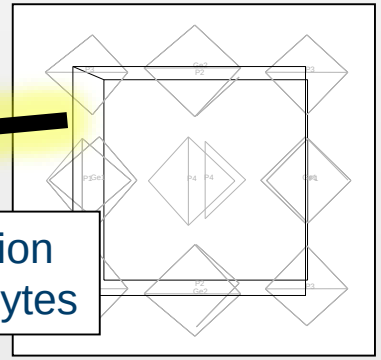
Transport in biological systems

Piezoelectric alloys

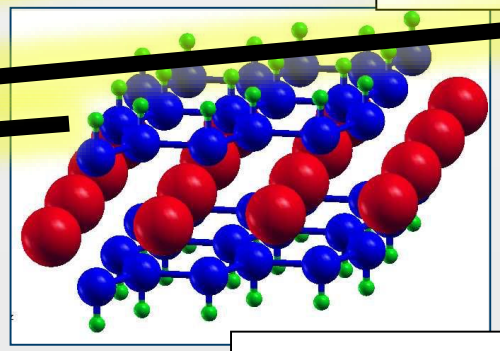


Defects in polymers

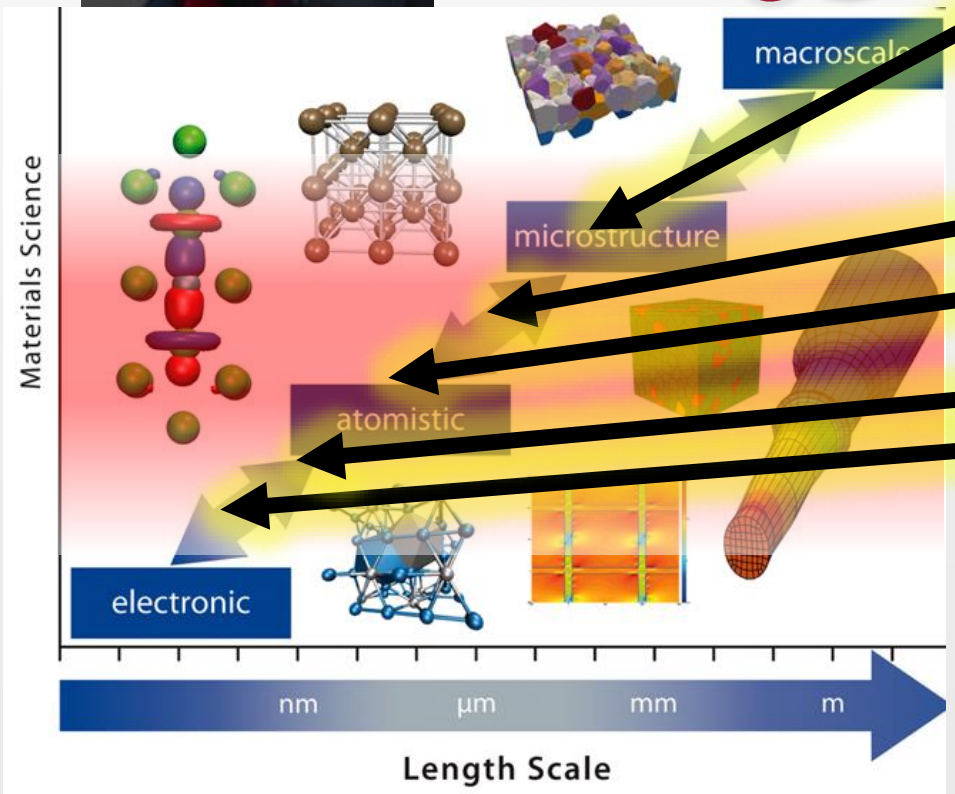




Ionic conduction battery electrolytes



Nanostructured boron compounds



Soumik Banerjee

Modeling materials relevant to energy conversion and storage devices

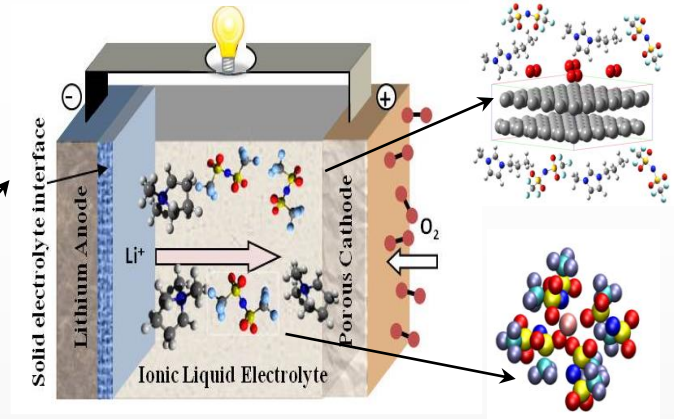
For more information, please visit:
http://www.mme.wsu.edu/~sbanerjee/

Contact information:
soumik.banerjee@wsu.edu
Office: 215 Sloan Hall

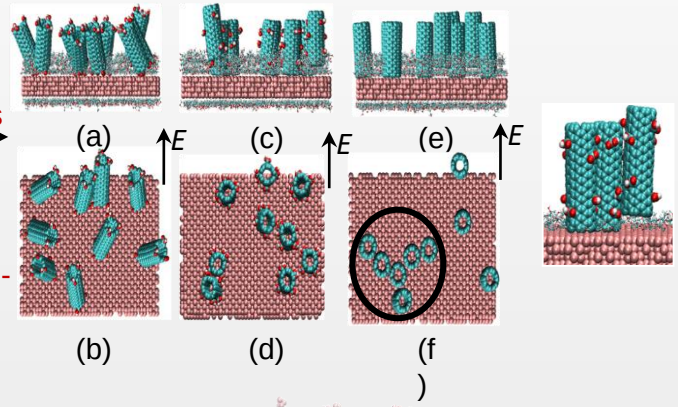
Research Interests

- Nanoscale transport phenomena
- Molecular modeling of materials
- Organic photovoltaic solar cells
- Electrolytes in Li batteries

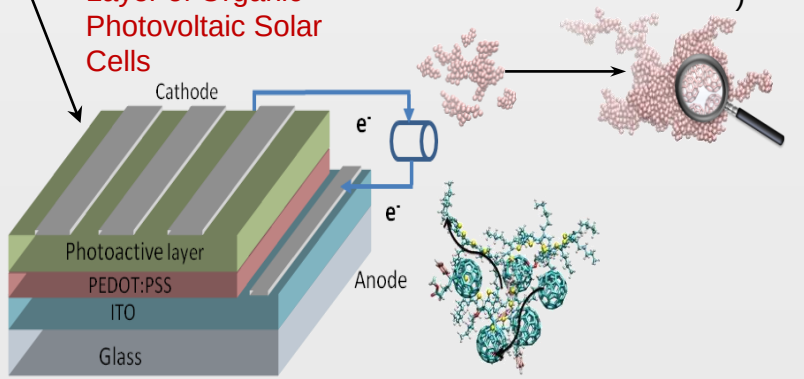
Identifying Novel Electrolytes for Lithium Batteries



Controlled Deposition of Aligned Carbon Nanotubes on Substrates for Super-capacitors



Modeling Solution-based Fabrication of Photoactive Layer of Organic Photovoltaic Solar Cells



Hussein M Zbib

Computational Mechanics and Materials Science (cmms.wsu.edu)

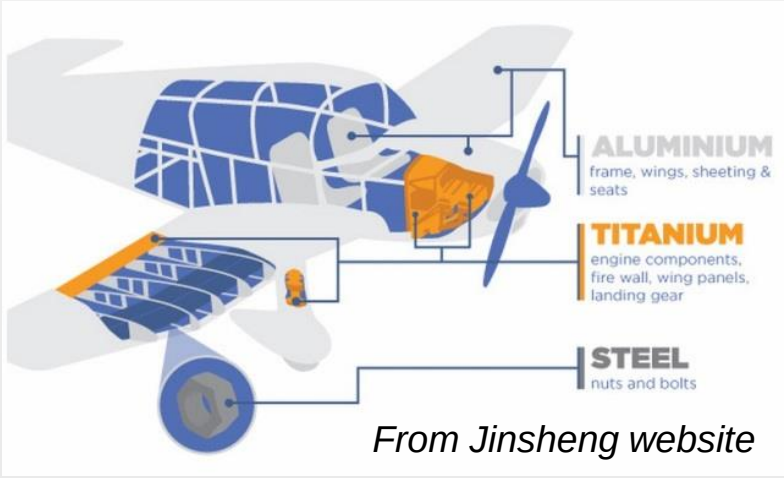
Thermo-mechanical behavior of solids:

Solve engineering and scientific phenomena spanning the length scale and occurring under extreme loading and environmental conditions, with emphasis on deformation, damage, fracture and material instabilities.

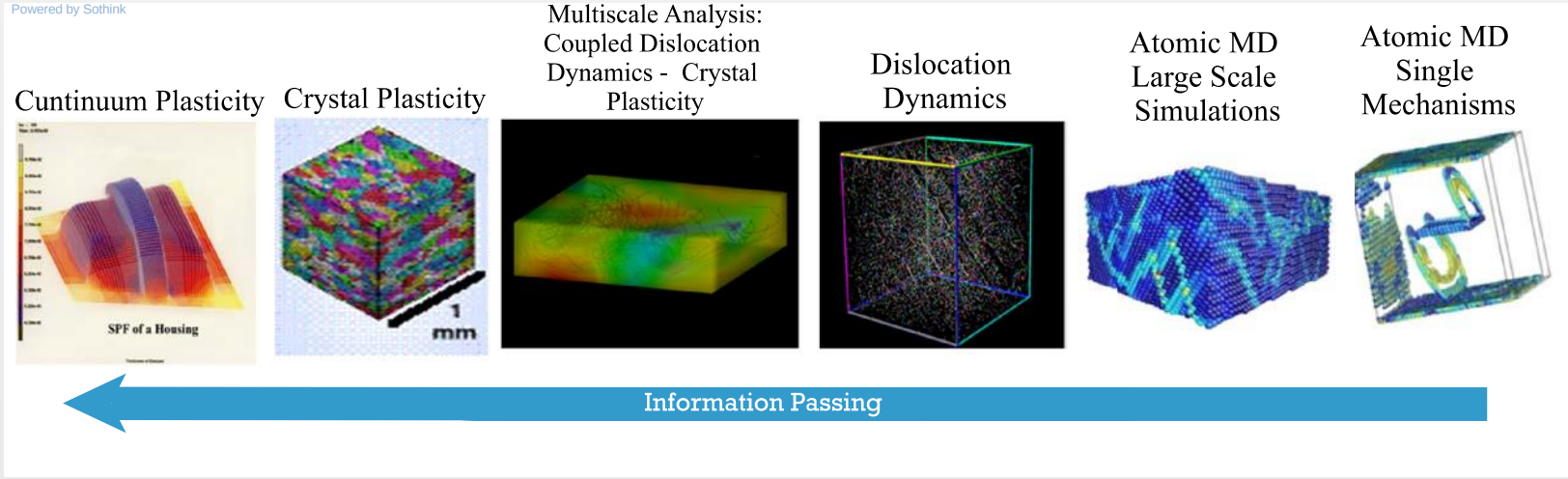
Develop multiscale models that are based on first principle calculations and link scales through information- passing

-Nanometer to micrometer: Investigate the mechanical performance of metals and composites with emphasize on nanolaminate metallic/ceramic structures, composites and thin films.

-Micrometer to macrometer: Investigate the behavior of metals and geological materials under extreme conditions: shockwaves, metal forming, high speed machining, superplastic forming, etc.



From Jinsheng website



Sinisa Mesarovic

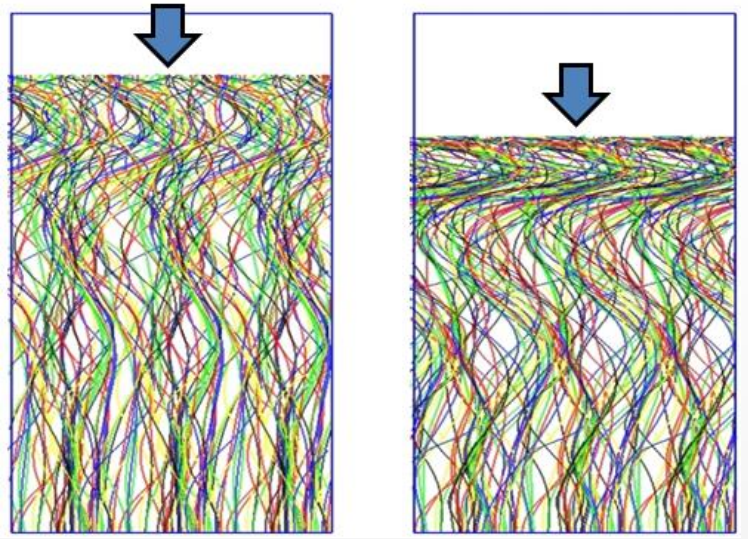
Research Interests: multiscale/multiphysics

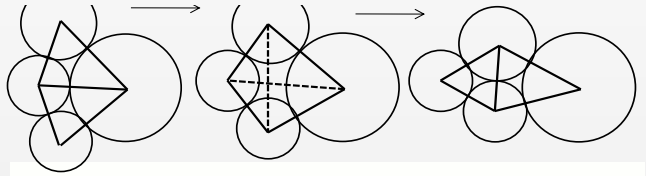
Plasticity of crystals and interfaces

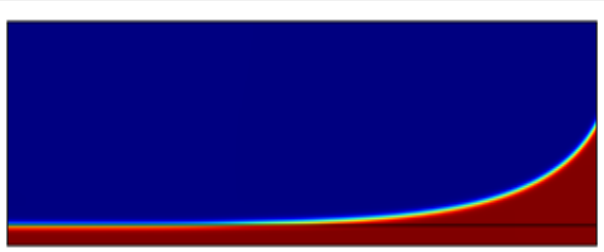
Micromechanics of granular materials

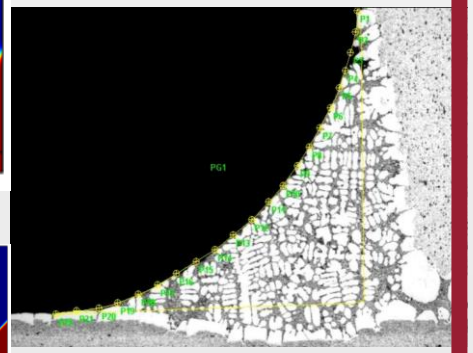
Collective behavior of carbon nanotubes

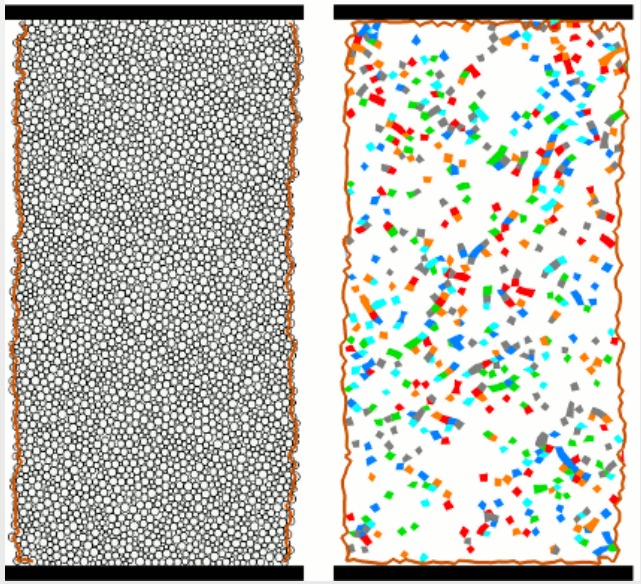
Phase-field models: Capillary flows, Phase transformations

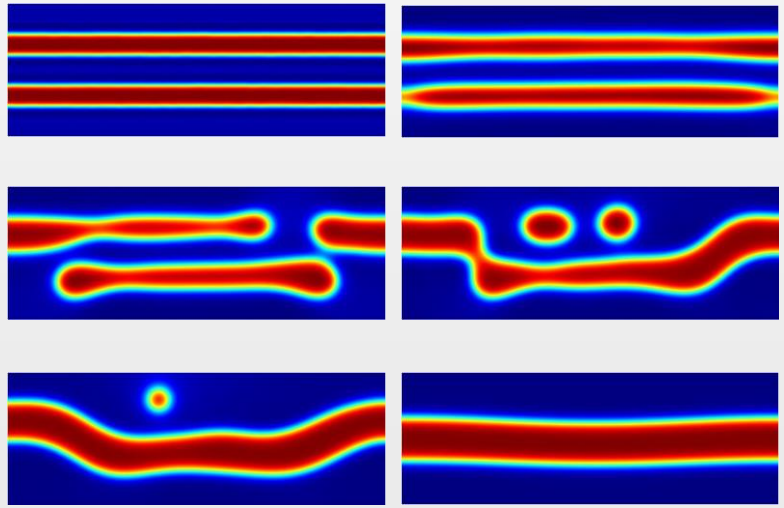








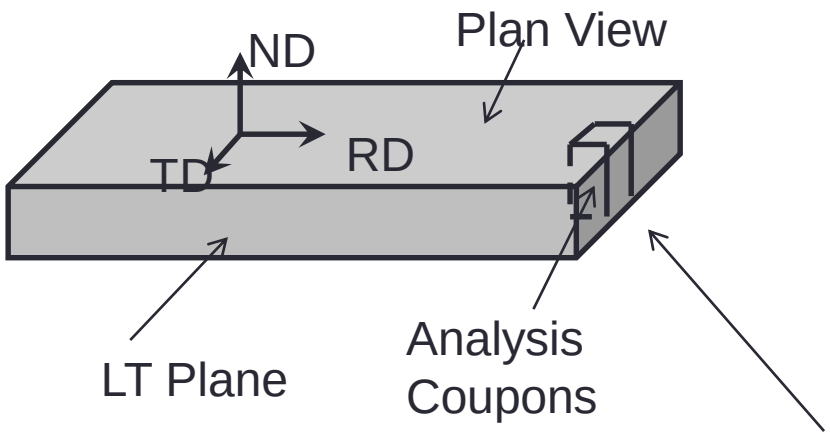




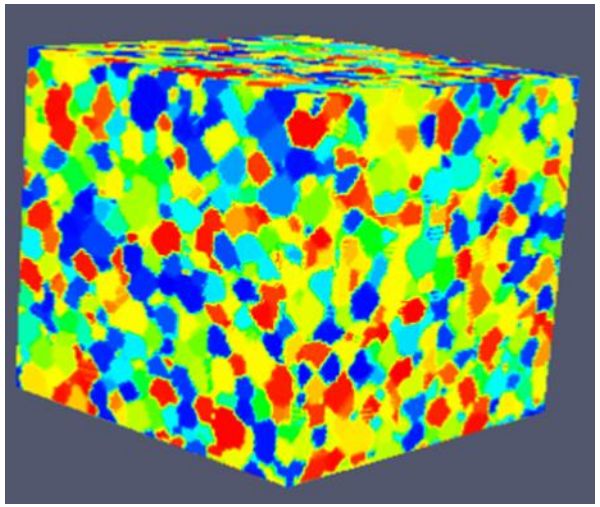
Microstructure Evolution in Al Alloys

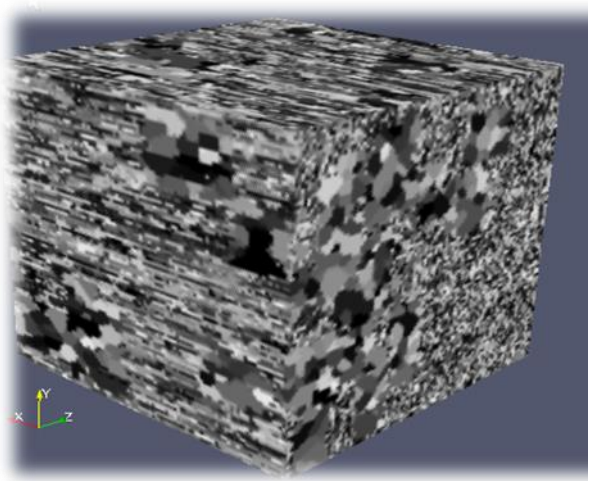
David Field (ME/MSE) with Kaiser Aluminum – Spokane, WA

http://planes.findthebest.com/l/65/Boeing-737-700C



- Experiments and modeling to efficiently predict evolution of aluminum structures.
- Develop predictive models so the producer knows precisely what to change in their process to obtain desired properties.





Jow Ding

Research Interests: Dynamic response of materials and structures (experimental characterizations, modeling, and simulation)

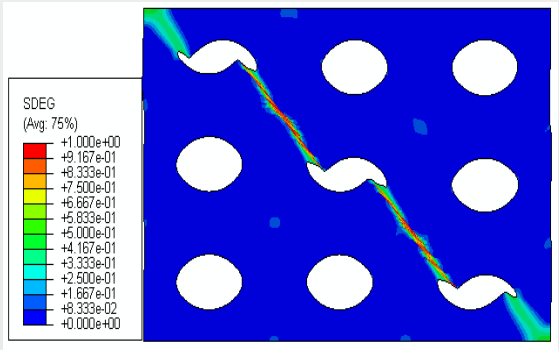
Applications:

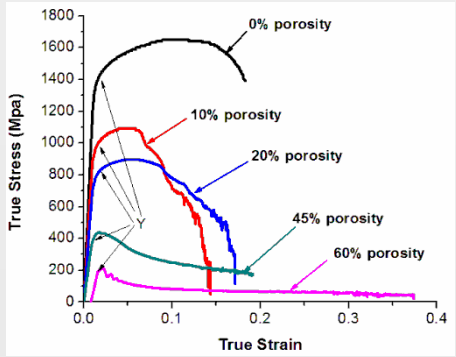
Experimental Characterization:

Split Hopkinson Pressure Bar Technique

Porous Ti6Al4V compressed at different loading rates

Modeling and Simulation:





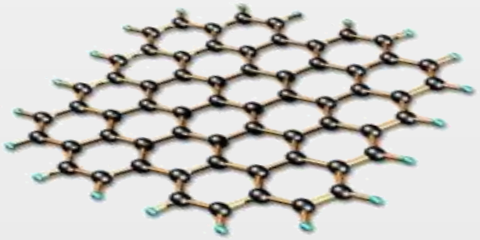
Simulated stress-strain responses as a function of porosity at a strain rate of 4000/s.

Other Materials Research

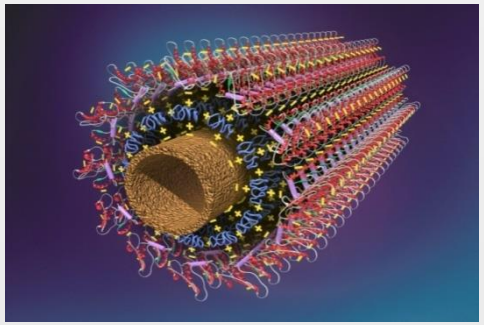
Yuehe Lin

- Synthesis and characterization of functional nanomaterials
- Materials and devices for sensing, bioimaging, and drug delivery
- Materials and systems for water monitoring and treatment
- Nanomaterials for fuel cells, batteries, and supercapacitors

Protein Cage



Graphene



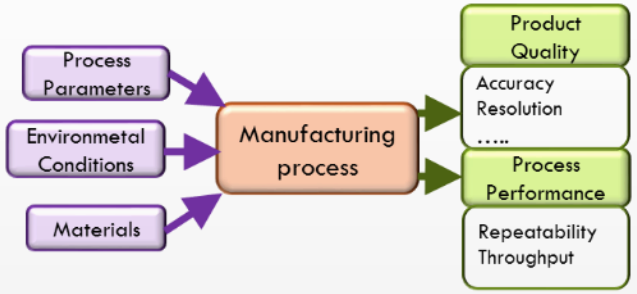
Carbon Nanotube

Indranath Dutta

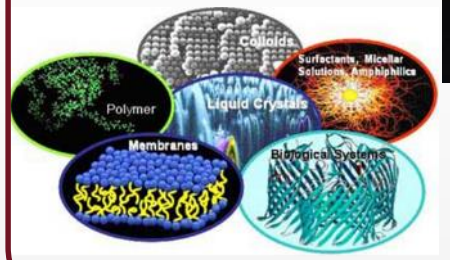
- **Electromigration-Interfacial Sliding Interactions in Micro-devices**
  - applications in back-end structures, 3-D interconnects
- **Thermal - Mechanical Interactions in Microelectronic Solders**
  - microstructural effects on creep, fracture (drop)
- **Electric Pulse Induced Cutting (EPIC):**
  - magnetic saw effect, electromagnetically induced fracture
- **Electro-Fountain Pen Nanolithography**
- **Tin Whisker Mitigation for Electronics**
- **Interconnects for Flexible Electronics**

Arda Gozen

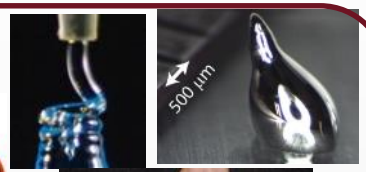
- Manufacturing Processes and Machinery Lab (MPML)



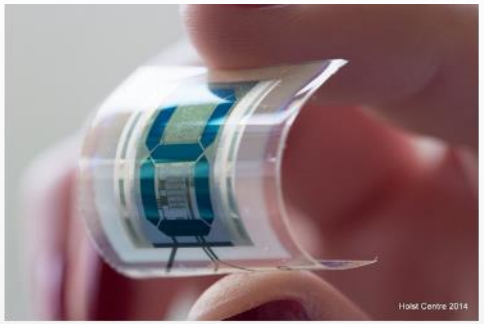
Soft-materials



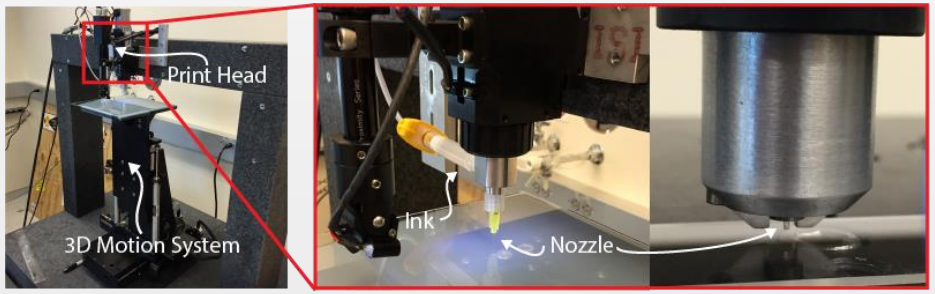
http://www.eu-softcomp.net/

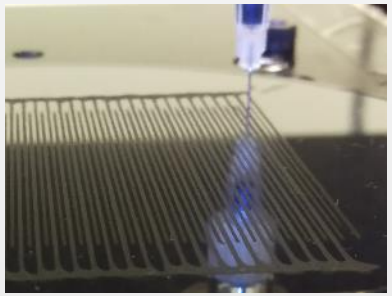


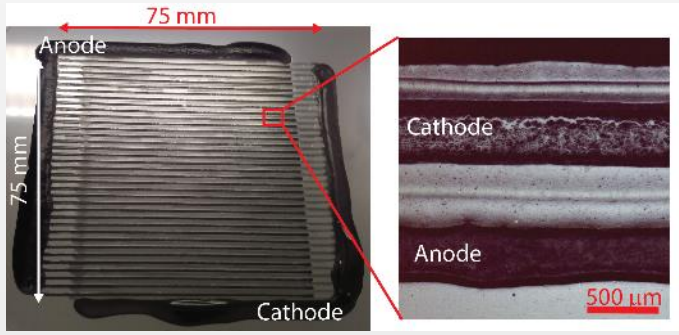
http://www.smooth-on.com/

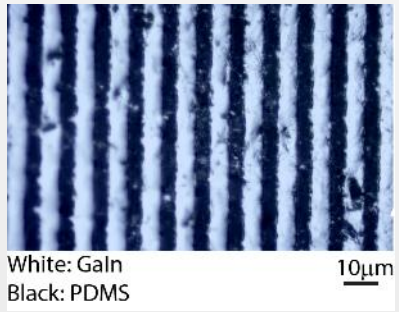


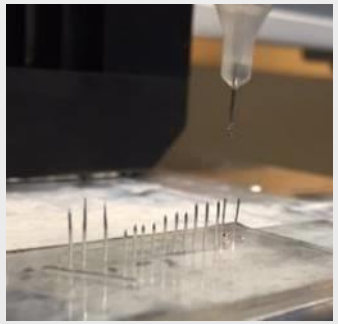
http://electroiq.com/blog/2014/07/printed-flexible-and-organic-electronics-a-growing-opportunity/

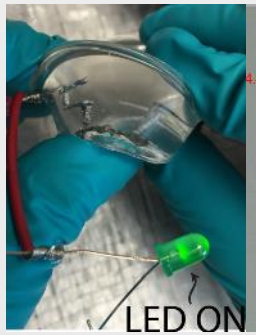


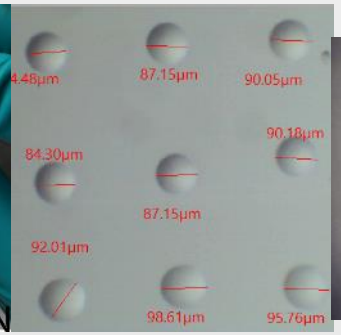


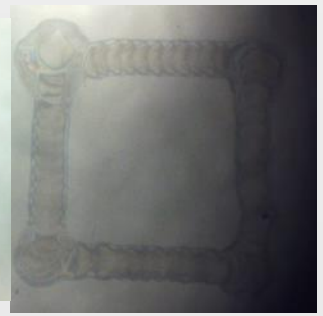












Xianming Shi, PhD, PE

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public.wsu.edu/~Xianming.Shi/

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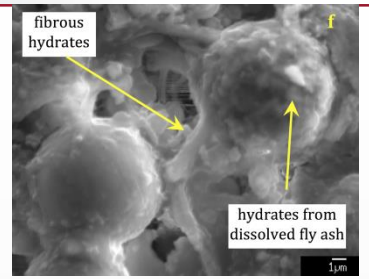
Research Interests

- Durable, sustainable, and smart pavements
- Sustainable materials for the built environment: e.g., value-added utilization of industrial or agro-based byproducts and recycled materials, multiscale characterization and modification
- Corrosion protection, infrastructure preservation or rehabilitation techniques and practices

Smart and Green Infrastructure Enabled by Materials



Mix Design (waste utilization)

Corrosion Inhibiting Admixtures

Self-healing Concrete

Deicer Scaling

Rebar Corrosion

Nanotechnology

Pervious Concrete
Self-consolidating concrete

Concrete Sealer

Online Corrosion Monitoring

Electrochemical Preservation/Rehab.

- Anti-icing Overlays
- Bioenergy Harvesting

- Self-healing coating
- Nanocomposite coating …

NSF

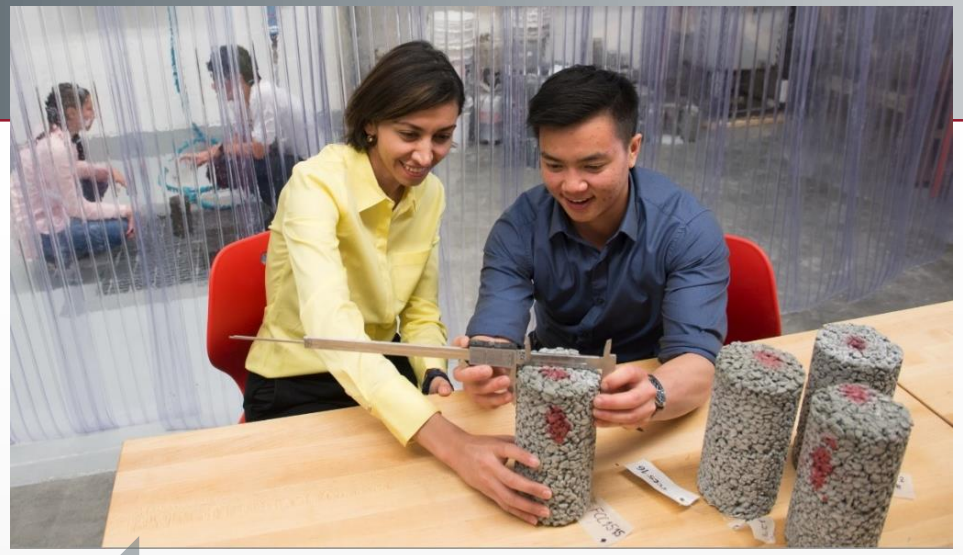
Center for Environmentally Sustainable Transportation in Cold Climates — CESTiCC

ILLINOIS CENTER FOR TRANSPORTATION

CLEAR ROADS
research for winter highway maintenance

CAMMSE

ACRP
AIRPORT COOPERATIVE RESEARCH PROGRAM



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Assistant professor, Civil & Environmental Engineering

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Office: PACCAR 248
Tel: 509-338-5582
Website: labs.wsu.edu/cmc/

LONG-LASTING CONCRETE INFRASTRUCTURE

Durable & Environmental Material Development

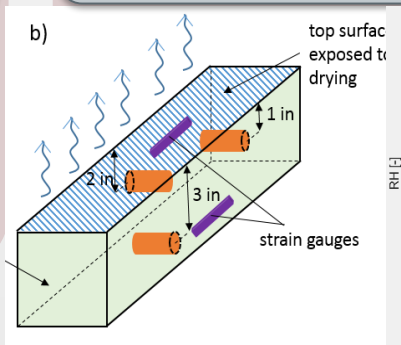
Sponsors: Boeing, Fiberglass Solutions, CESTiCC

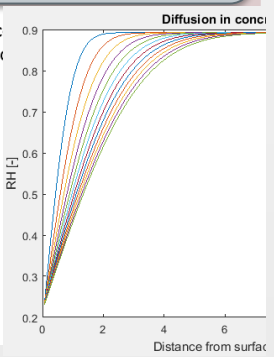
Environmentally Friendly Infrastructure Design

Sponsors: American Concrete Institute (ACI), WA DOT, CESTiCC, PacTrans

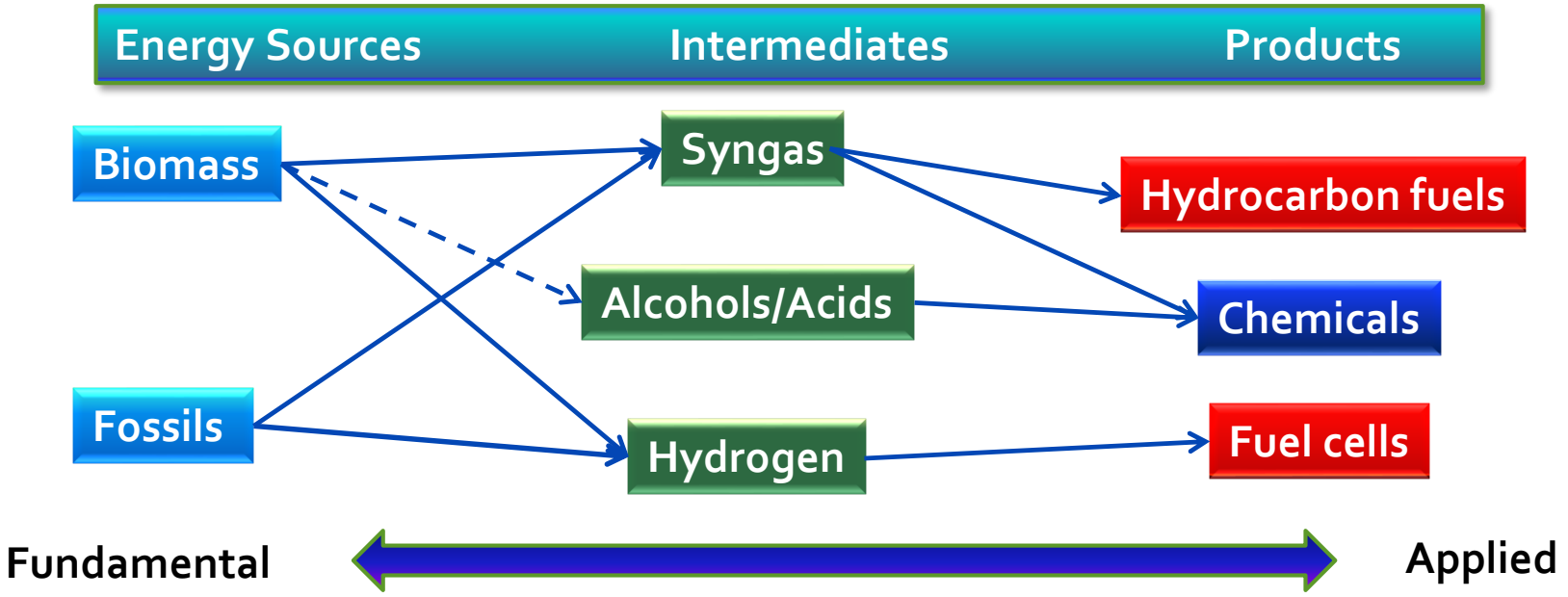
Environmental & Loading Performance Prediction

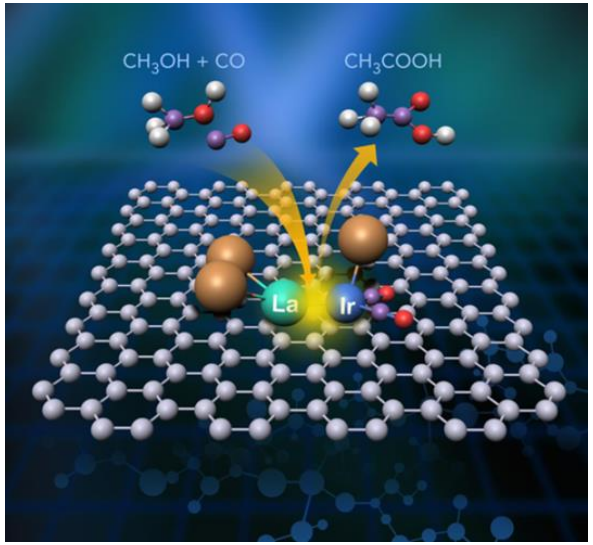
Sponsors: Idaho DOT, CESTICC, Decagon Devices





Yong Wang Group: Innovations in Catalysis and Reaction Engineering to Address the C and Energy Efficiency Issues in Sustainable Conversion of Energy Sources





Approaches

- Integrated experimental and theoretic approach
- Leveraging state-of-the-art capabilities at national labs
- Catalysis Reaction engineering innovations for process intensifications

Yong Wang, Voiland Distinguished Professor in Chemical Engineering
wang42@wsu.edu, http://www.chebe.wsu.edu/Faculty/YWang.html

238 peer reviewed publications (H index=59, >15,000 citations)
260 issued patents (including 104 issued US patents)

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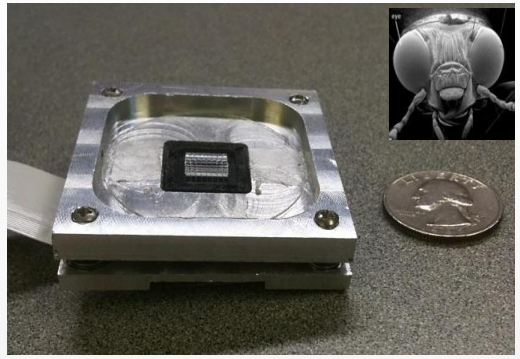
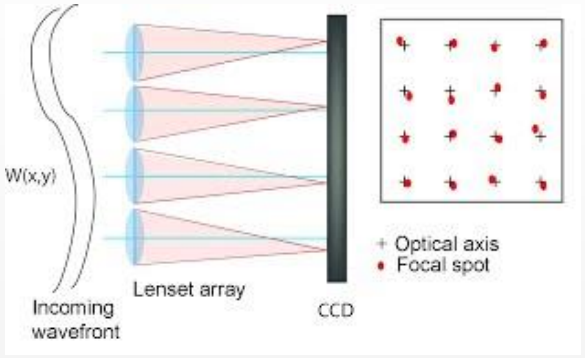
Institute for INTEGRATED CATALYSIS

Lei Li

Design and Fabrication of Integrated Photonics Systems



Artificial compound eyes

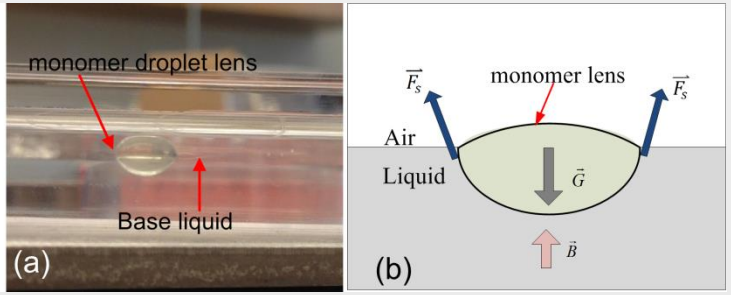


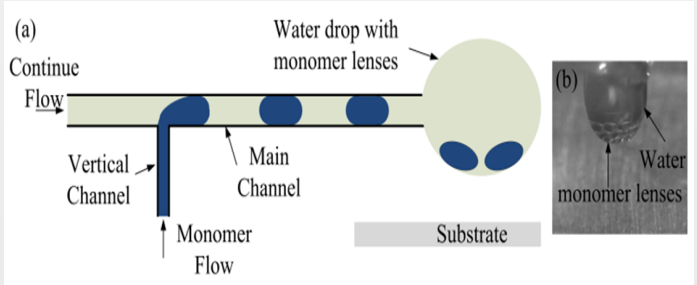
Sensing

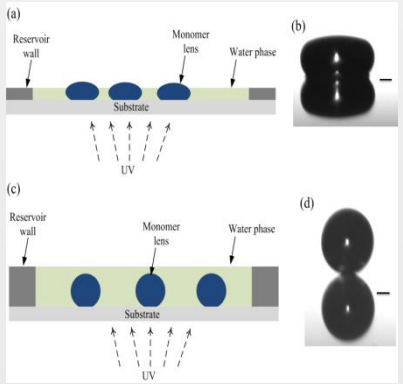
Wearable and point-of-care devices

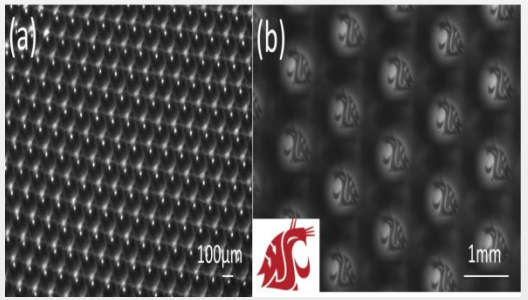
Illumination

Direct printing of freeform optics





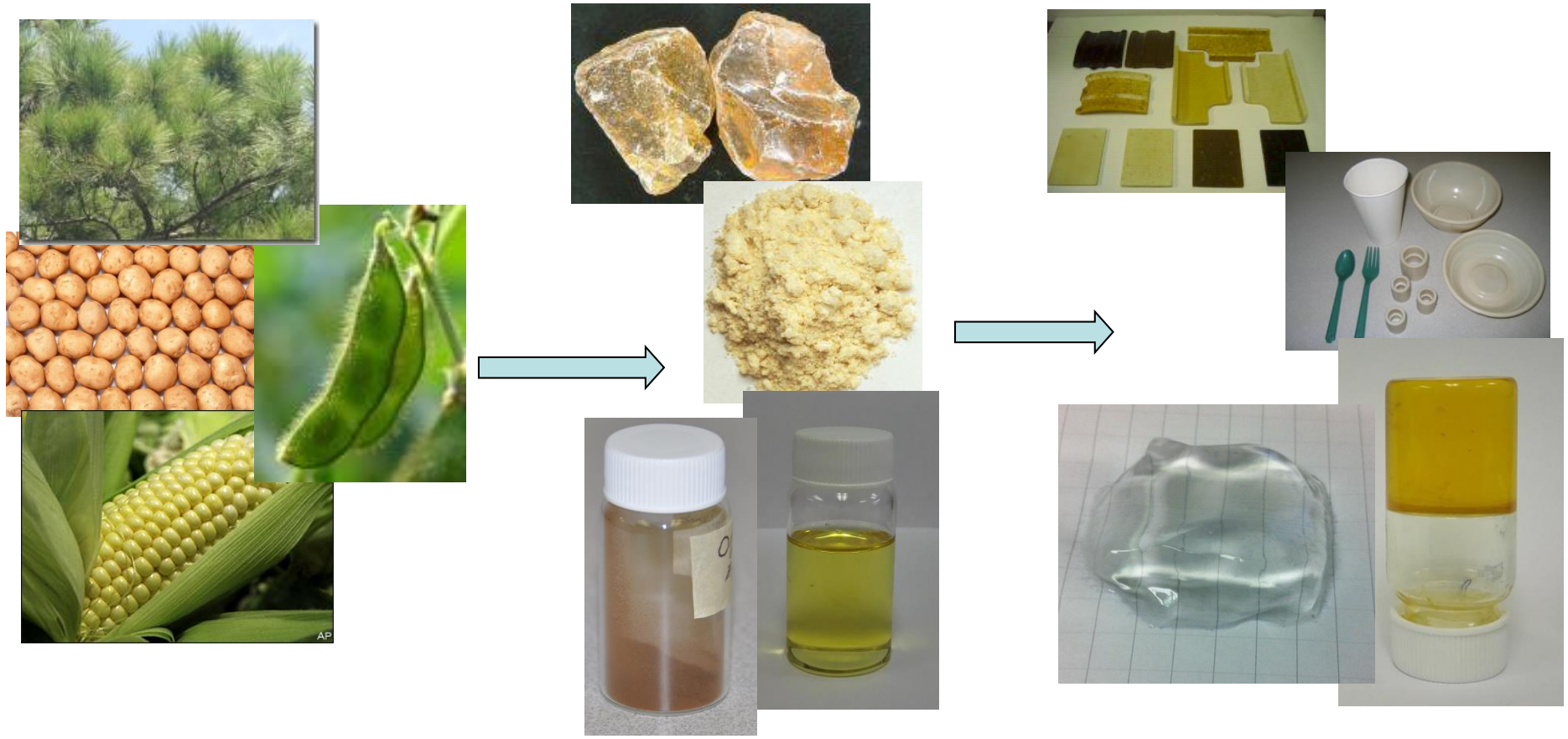




Jinwen Zhang

Biobased Polymer Materials Research

Transform abundantly available renewable feedstock to value-added polymer products

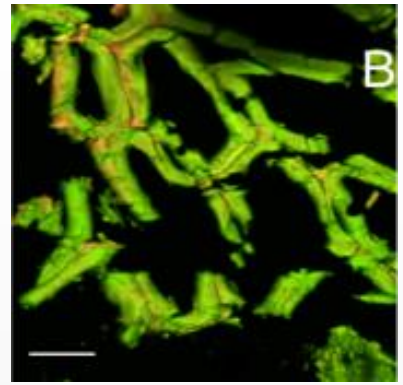


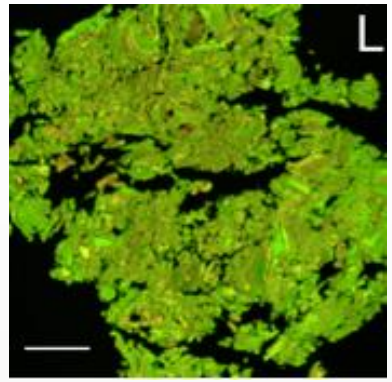
Renewable resources

Chemicals & Polymers

Biobased polymer products

Michael Wolcott, Regents Professor (Ph.D., Virginia Tech, 1989; @WSU since 1996)





Research:

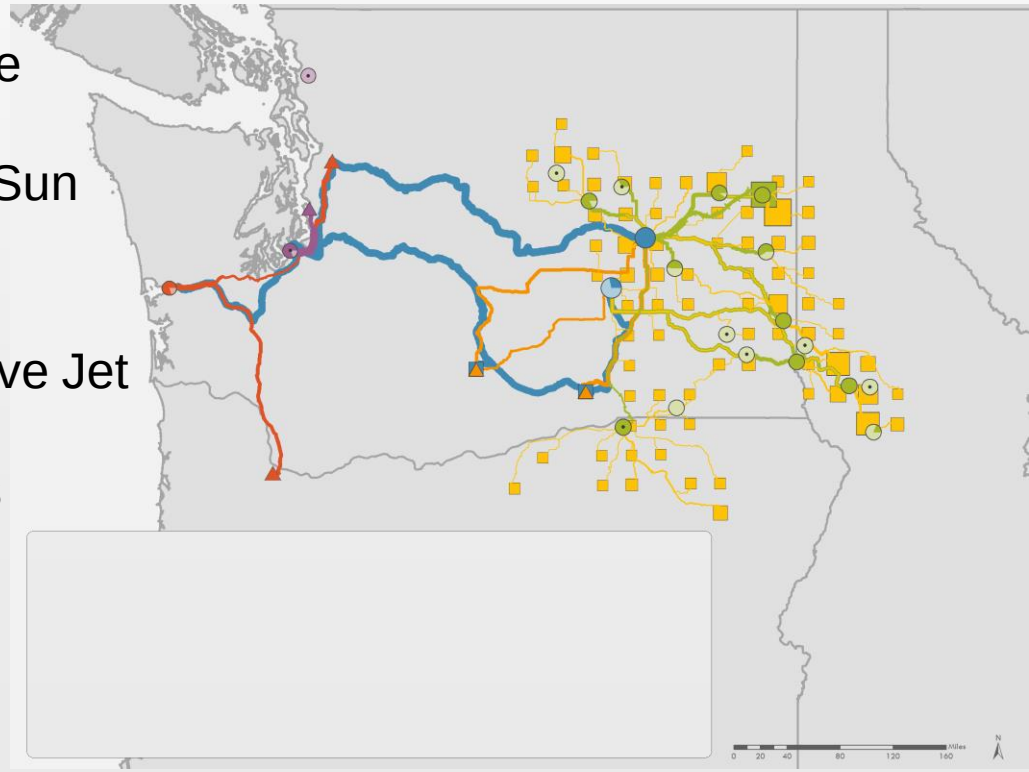
- Biofuels and Bioproducts
- Polymers and Composites
- Supply Chain Modeling for Sustainability Analysis

Ongoing Research:

- Supply Chain Modeling for Aviation Biofuels Production (FAA - ASCENT
- A Pilot Supply Chain for Advanced Manufacture of CLT in the Pacific Northwest (USFS)
- Amorphization Milling for Digestible Wood Powders (USDA Sun Grant)

Notable Activities:

- Director – ASCENT – FAA Center of Excellence for Alternative Jet Fuels and the Environment
- Co-Director – NARA, The Northwest Advanced Renewables Alliance (USDA NIFA)
- Interim Co-Director –The WSU-PNNL Bioproducts Institute



Center for Bioplastics and Biocomposites (CB^2)

Vikram Yadama and others, working with 3M, Hyundai, Ford, EcoPlastics, BioProducts, Newell Rubbermaid, and many others

- NSF-Funded Industry/University Cooperative Research Center (I/UCRC)
- CB^2 **develops knowledge** about an array of high-value products from agricultural feedstocks:

Plastics, Coatings, Adhesives, Composites

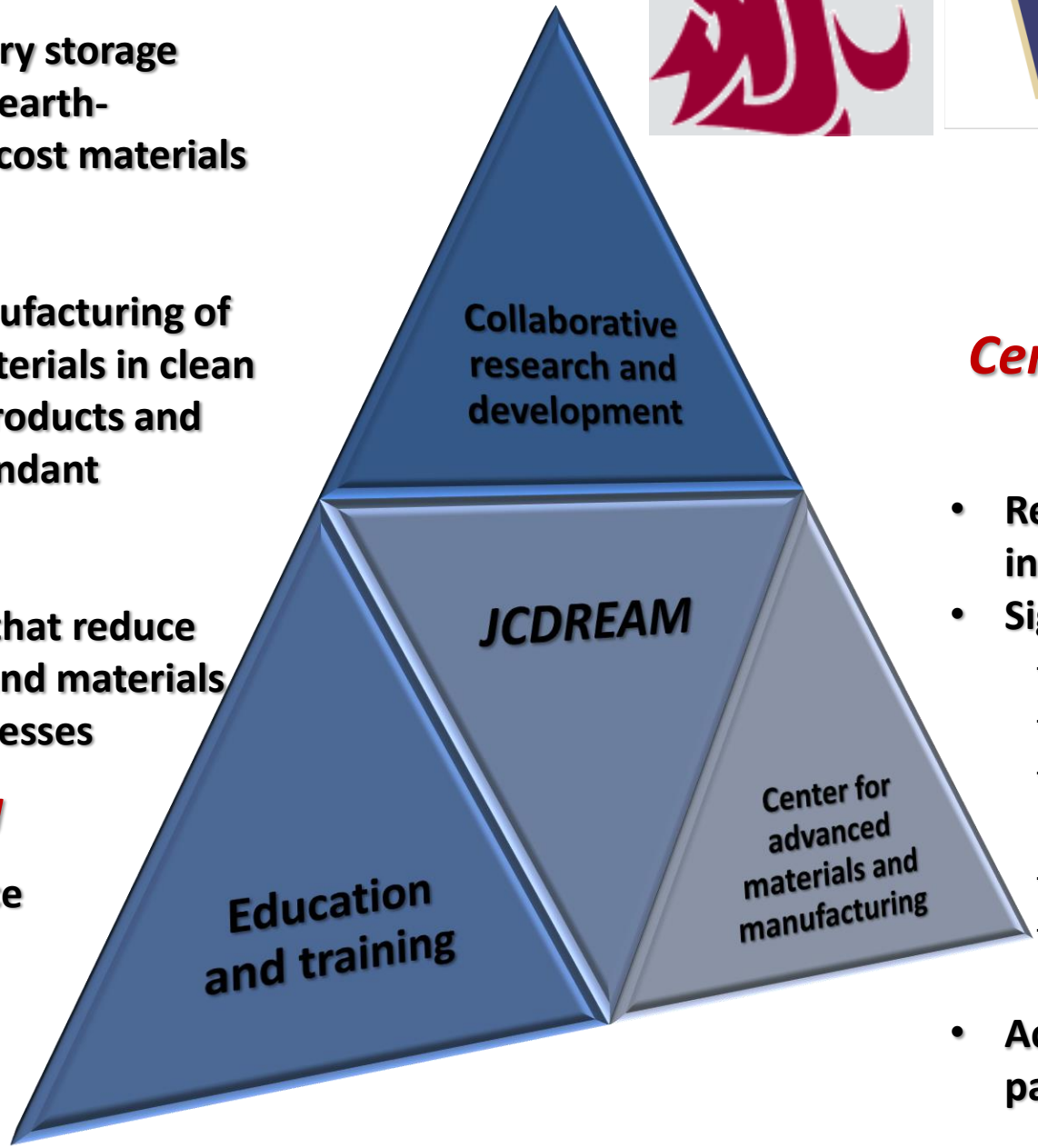
JCDREAM: Earth Abundant Materials Research and Education in Washington State

Clean energy and transportation technologies

- **Renewable energy and battery storage technologies that substitute earth-abundant materials for high cost materials with limited supply**
- **Scalable processing and manufacturing of functional and structural materials in clean energy and transportation products and components from earth-abundant materials**
- **Technologies and processes that reduce the environmental impacts and materials waste in manufacturing processes**

Education and training

- **Training the skilled workforce necessary for the successful commercialization and integration of earth-abundant technologies**



Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

Center for advanced materials and manufacturing

- **Responsive research and development infrastructure**
- **Signature user facilities:**
  - **Scalable Nanomanufacturing**
  - **Additive manufacturing**
  - **Batteries and energy storage research**
  - **Materials joining**
  - **Computational modeling and simulation cyber-infrastructure**
- **Accessible to JCDREAM community of partners**