Materials Science & Engineering

A hub for *creativity*, *inventions* & *innovations* to make the world a better place…

Open House Presentation
Spring 2021

Please visit us @ mse.rutgers.edu or on
Instagram @ rutgers_mse_official_ig
LinkedIn @ linkedin.com/groups/152348/

RUTGERS
UNIVERSITY

Materials Science & Engineering Open House 14 April 2021

Your hosts…

Prof. Lisa C. Klein,
Chair
licklein@soe.rutgers.edu

Prof. E. Koray Akdoğan,
Undergrad. Prog. Dir.
licklein@soe.rutgers.edu

Materials Science & Engineering
"*What's unique about our department?*"

- Most of our students get involved in the lab while they are undergrads
- Many of our juniors work on research for their capstone course
- Our students submit talks to national professional societies
- Getting involved in research prepares you for industry and graduate school

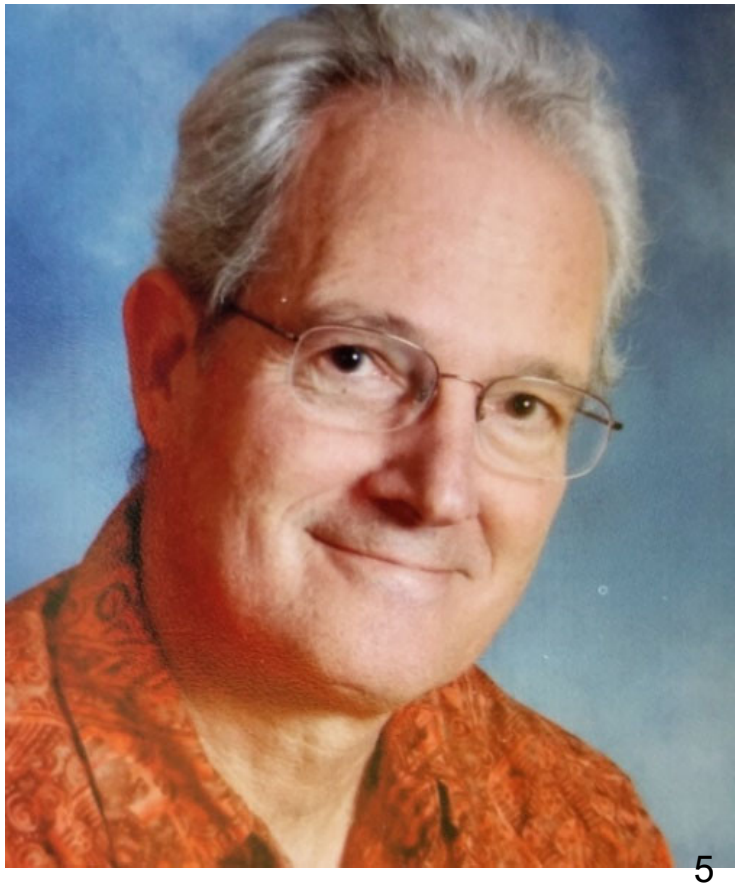
A Sampling of Research in Materials Science & Engineering @ Rutgers

- **Part 1**
  - Dr. Dunbar Birnie
  - Dr. Ashutosh Goel
  - Dr. Richard Haber
- **Part 2**
  - Dr. Lisa Klein, Chair
  - Dr. Richard Riman
  - Dr. Ryan Sills
- **Part 3 - Our Undergraduate Director**
  - Dr. Koray Akdogan

Prof. Dunbar P. Birnie, III

Department of Materials Science and Engineering
Rutgers University
dunbar.birnie@gmail.com

- **Solar Cell Design and Processing**
- **Electrochemical Materials & Devices**
- **Optical Modeling**
- **Innovation & Entrepreneurship**



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Prof. Birnie III, Research Highlights

Schematic of Lithium Battery and Scanning Electron Microscope Micrograph

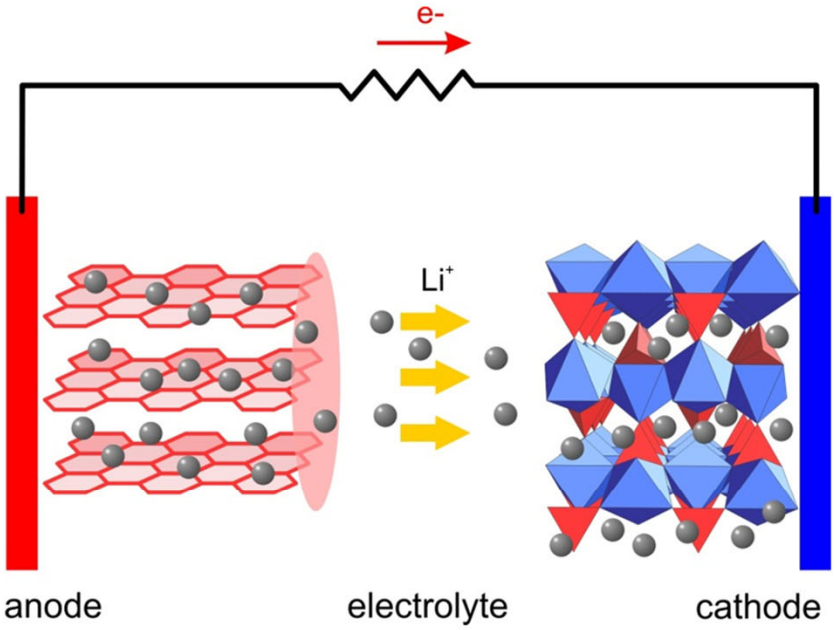
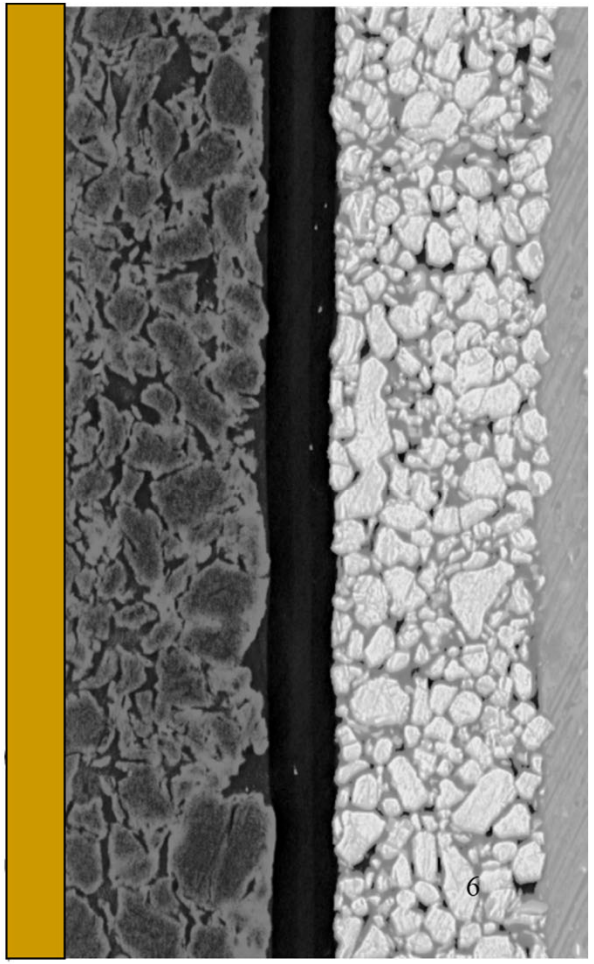


Figure from http://www.intechopen.com/books/metal-ceramic-and-polymeric-composites-for-various-uses/composite-cathode-material-for-li-ion-batteries-based-on-lifepo4-system-



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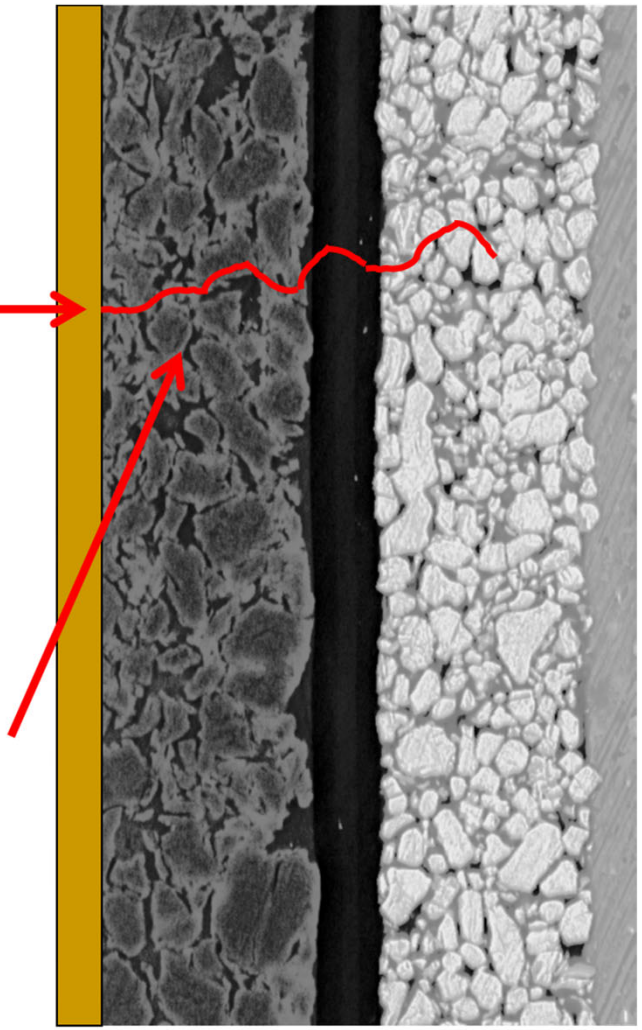
Prof. Birnie III, Research Highlights

Transport Mechanism

Lithium ions must navigate around granular cathode and anode particles → following "tortuous" path



Prof. Birnie III, Research Highlights

Our New Efforts in Templating and 3D Characterization

- A Recent Poster by Graduate Student Anand Patel:

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THE STATE UNIVERSITY OF NEW JERSEY

Porosity Interconnection Pathway Visualization and Quantification in 3D

Anand Patel, Department of Materials Science and Engineering, Rutgers University
PI: Dr. Dunbar Birnie, III, Department of Materials Science and Engineering, Rutgers University
Dr. Deborah Silver, Department of Electrical and Computer Engineering, Rutgers University

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1.Motivation

With advancement in science and technology, the need of renewable energy and energy storage is growing exponentially. This calls for efficient solar devices and batteries. Many of these electrochemical materials systems require ion diffusion and motion through 3D microstructures to deliver the desired device functionality. The best example is lithium ion batteries, which require Li+ motion through liquid electrolytes and in-to/out of anode and cathode grain lattices where the lithium atoms stably reside when resting..

In recent years, visualization capabilities have mushroomed in complexity: 2D still pictures, video, 3D tomographic imaging, moving into time resolved spatial data – and further, spatially co-registered chemical and spectroscopic information. All these imaging modalities yield larger and larger datasets with more specific local information on pore structures, interconnections and properties. Using, X- ray micro-computed tomography (-CT), skeleton

4. Image Analysis Results

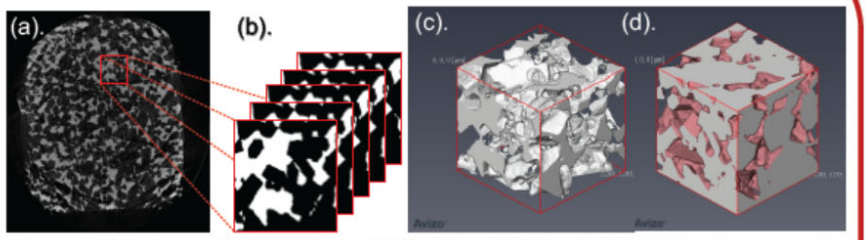
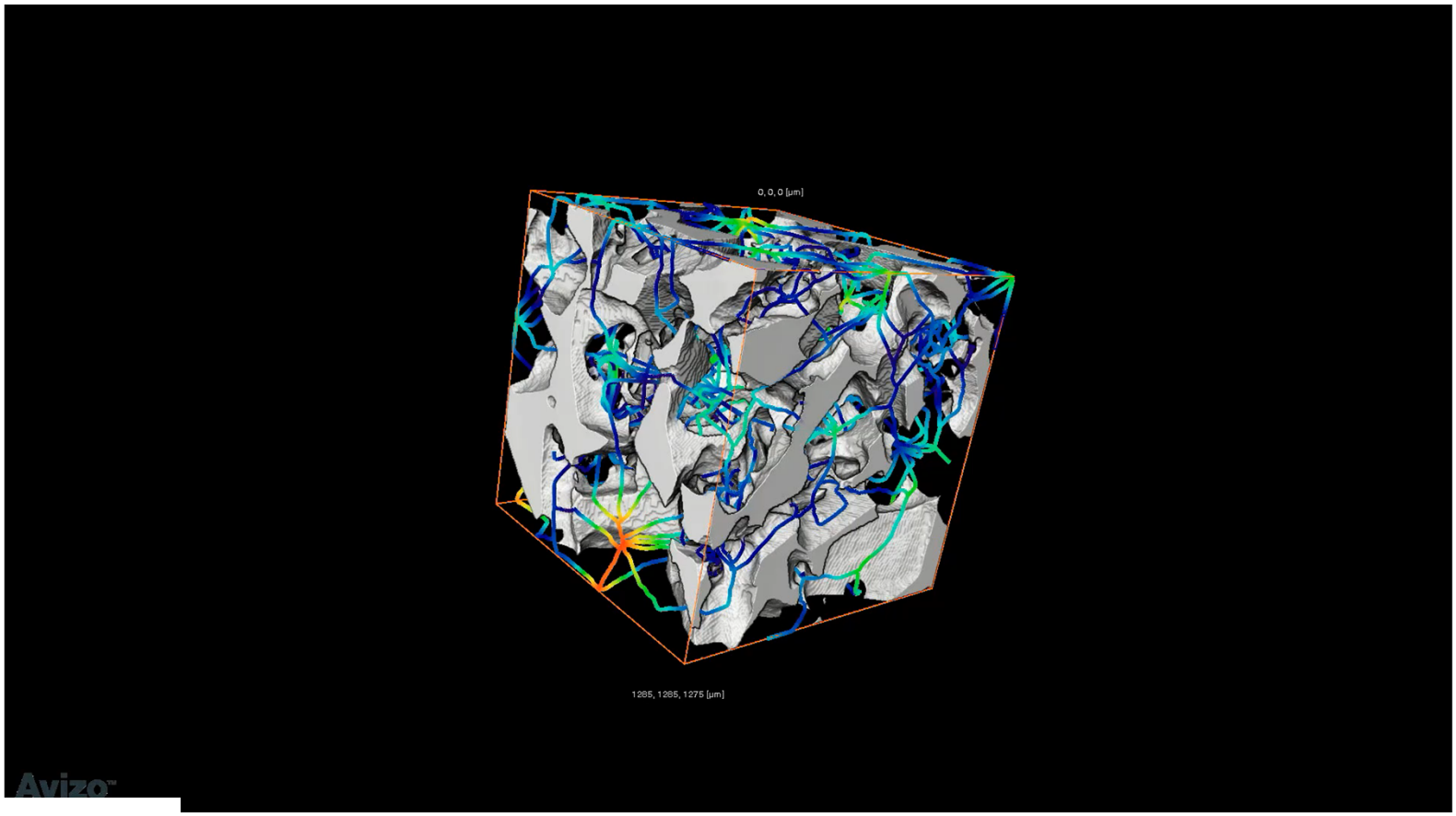


Figure 2. (a). Greyscale Image (from X-Ray Nano-CT Scan) of PDMS cube prepared using sugar templating process. (b) Randomly selected local region (red square) which was cropped (258 X 258 X 256 pixels) and segmented using Avizo auto thresholding option (1pixel = 4.99μm). White represents PDMS and black represents air. (c).

Prof. Birnie III, Research Highlights

Connectivity of Pathways in 3D →Measuring Tortuosity →
→ Working on Methods to Make Easier Flow Paths



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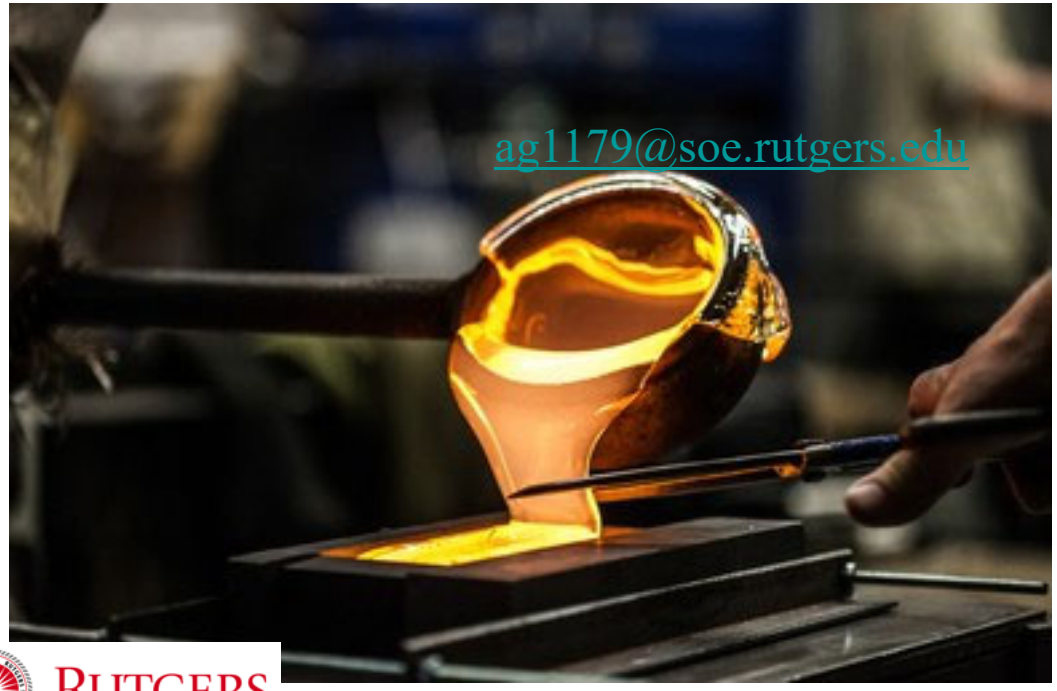
Prof. Ashutosh Goel

Department of Materials Science and Engineering
Rutgers University
ag1179@soe.rutgers.edu

Specializing in pioneering research on glass science and technology…



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Prof. Ashutosh Goel-Overview

Welcome to the Glass Age

Throughout history, materials have transformed society and culture. There was Stone Age, the Bronze Age, and the Iron Age. This is the Glass Age.

According to Steven Johnson (Science Author), *"Glass is arguably the most important material of the last thousand years".*

One of the six innovations that made the modern world.

Do you know who invented Gorilla glass?

If the iPhone had shipped with its original plastic screen rather than Gorilla glass, the whole experience would have been less magical!

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Prof. Ashutosh Goel-Overview

A famous alumnus specializing in glass technology

Dr. Matthew Dejneka
Research Fellow, Corning Incorporated
Co-Inventor of Corning Gorilla® Glass

OK! But, what's so special about it?

B.S., Ceramic Science and Engineering
1987 – 1991
Rutgers, The State University of New Jersey

Ph.D., Ceramic Science and Engineering
1991 – 1995
Rutgers, The State University of New Jersey

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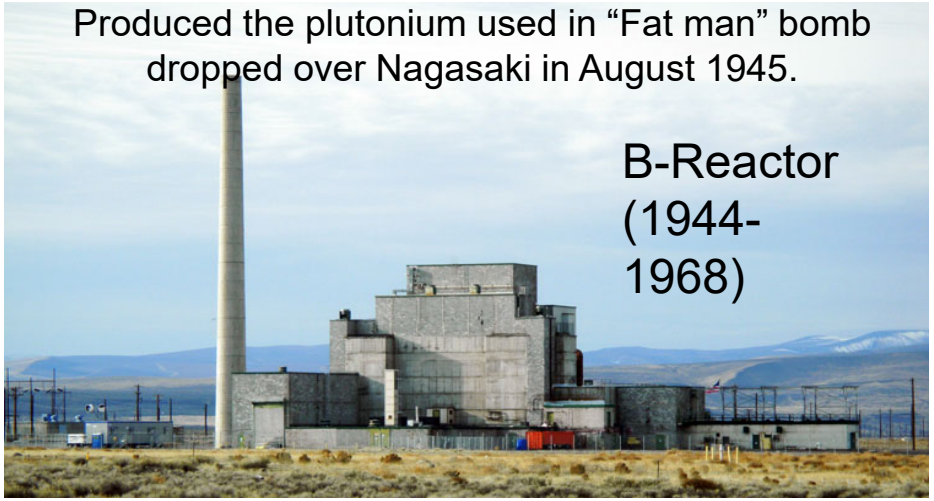
Prof. Ashutosh Goel-Overview

What do we do in glass research?



Bioactive glasses for bone and tissue regeneration

Glasses for immobilization of nuclear waste

The nuclear waste from the production of nuclear electrical energy of one person’s entire life is contained in the glass in hand.

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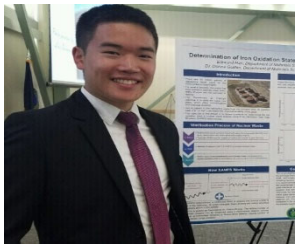
Prof. Ashutosh Goel-Opportunities

Research opportunities for undergraduate students



- US DOE scholarship ($7,500)
- Roy G Post Scholarship ($2,500)
- Summer Internship at Idaho National Laboratory
- Co-author in 2 journal articles

Edmund Han
Ph.D. Student
University of Illinois at Urbana-Champaign
MSE-Rutgers, Class of 2017

Muheez Rehman
Lead Engineer
Honeywell Aerospace
MSE-Rutgers, Class of 2016

Allyson Maron
Healthcare Application Scientist
Croda
MSE-Rutgers, Class of 2015

TechAdvance
Commercializing Rutgers Technologies

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Prof. Richard Haber

Dept of Materials Science & Engineering
rich.haber@rutgers.edu

Haber Group focus:

1. Additive manufacturing of ceramics, metals and composite materials
1. Synthesis, processing and characterization of strategically critical materials to the defense of the US, soldier protection armor and hypersonic materials
2. Group is composed of 7 graduate students, 3 PhD researchers, and 6 undergraduate researchers. (We typically have 15-20 undergraduates working in our group)
3. We have the most modern equipment of any MSE department in the US in these areas with ~$5M of new facilities added in the past 5 years

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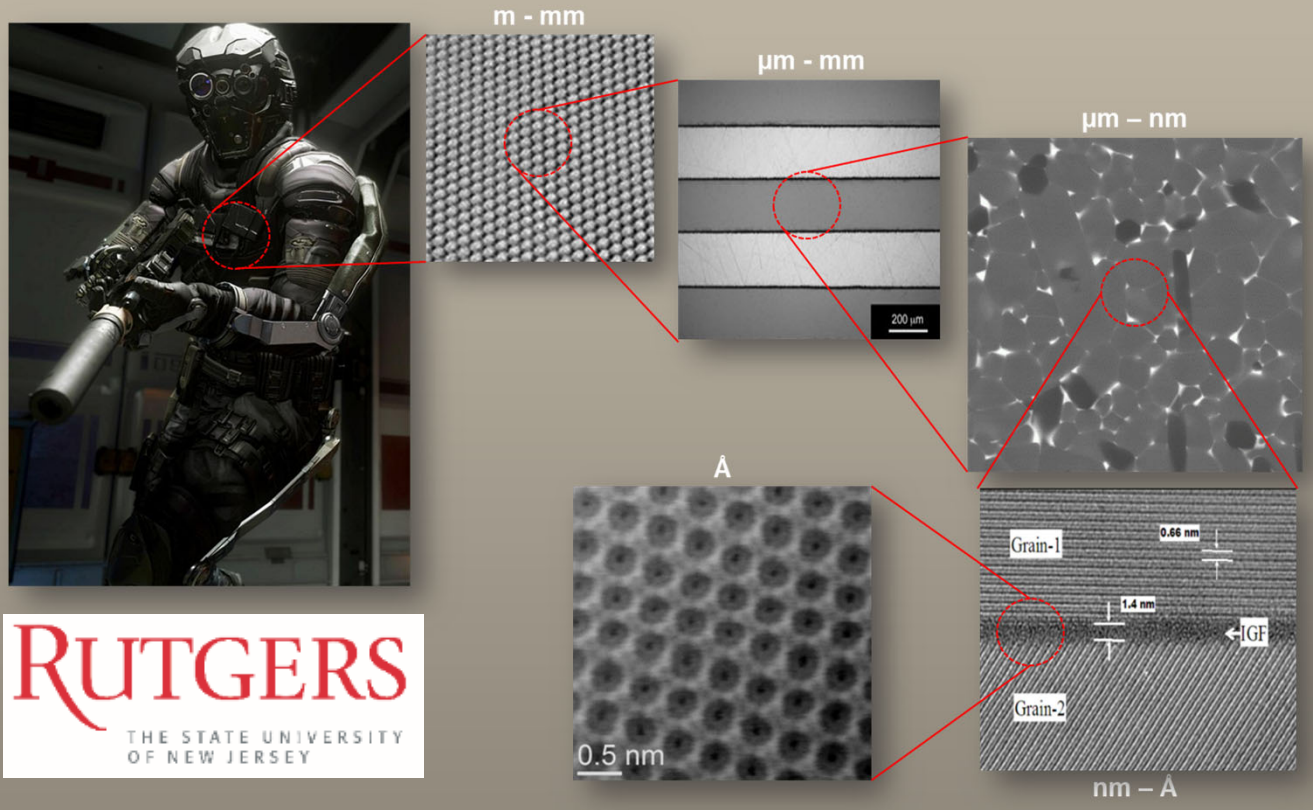
Prof. Haber Research Highlights

Vision: Engineered Ceramics Across All Length Scales for Unparalleled Armor Performance



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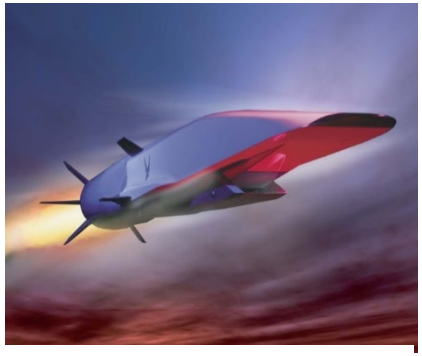
Prof. Haber Research Highlights

Hypersonic Materials



X-51 Concept
Image Courtesy of NASA

Can we move from concept to an operational hypersonic flight vehicle?

X-51 Test Vehicle
Image Courtesy of NASA

- Fabrication technologies
  Can parts be made to near net shape at reasonable cost? ✓
- Properties
  Do measured properties reflect intrinsic behavior? **In progress**
- Performance
  Improvements needed in resistance to oxidation, thermal shock, thermal cycling resistance, and creep **Future Research**

Prof. Haber Research Highlights

Stereolithography

Stereolithography has been most developed process for ceramic AM

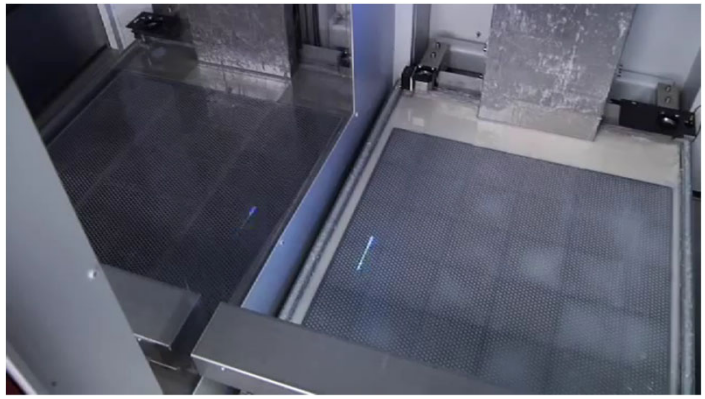
Very effective method for creating ceramic preforms

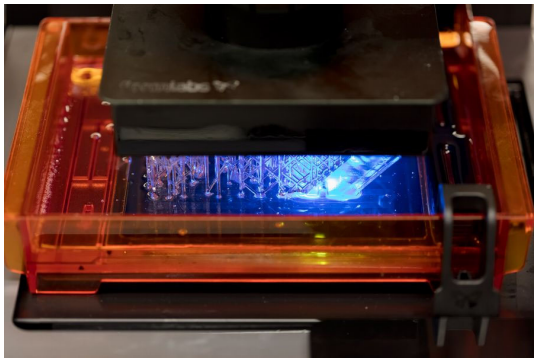
High fidelity surfaces and internal features

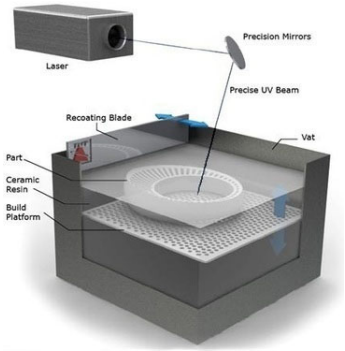
~100-200 μm features (supports needed)

Challenges:
- Material refractive properties
- Solids loading
- Dispersion effectiveness

Vendors: 3D Systems, Lithoz, Admatec, Formlabs





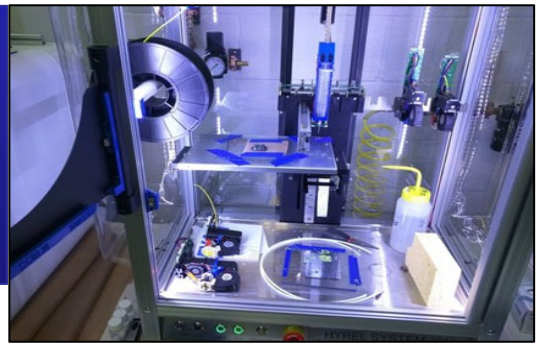


Prof. Haber Research Highlights

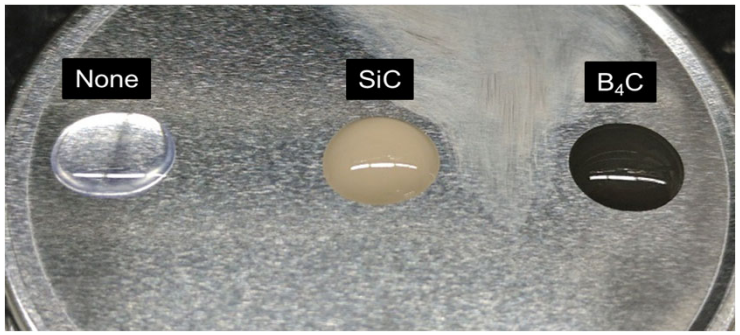
Haber Group focus is on material development and demonstration of heterogeneity

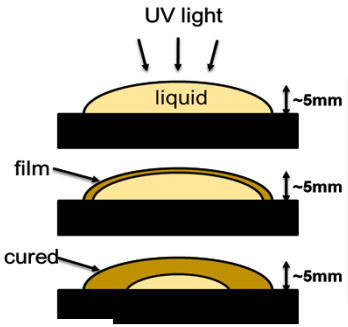
SLA: Development of science for carbide-based resins for UV photocuring

Direct Write: Suspension development for B_4C and SiC

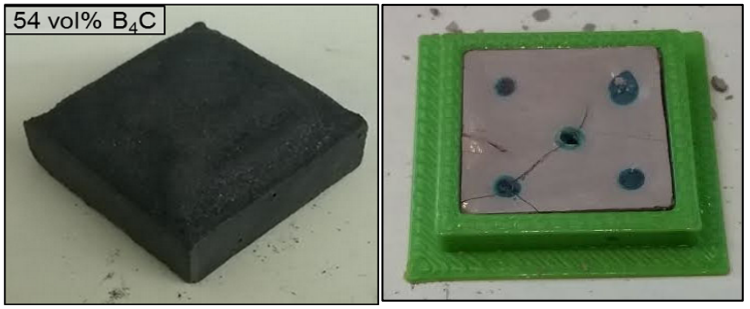


Hyrel 30 System for direct writing of ceramic suspensions





Photocuring trials for 20 vol.% loaded ceramic suspensions



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  - Dr. Lisa Klein, Chair
  - Dr. Richard Riman
  - Dr. Ryan Sills
- **Part 3 - Our Undergraduate Director**
  - Dr. Koray Akdogan

Prof. Lisa C. Klein, Chair

Dept. of Materials Science & Engineering
Rutgers University
licklein@soe.rutgers.edu

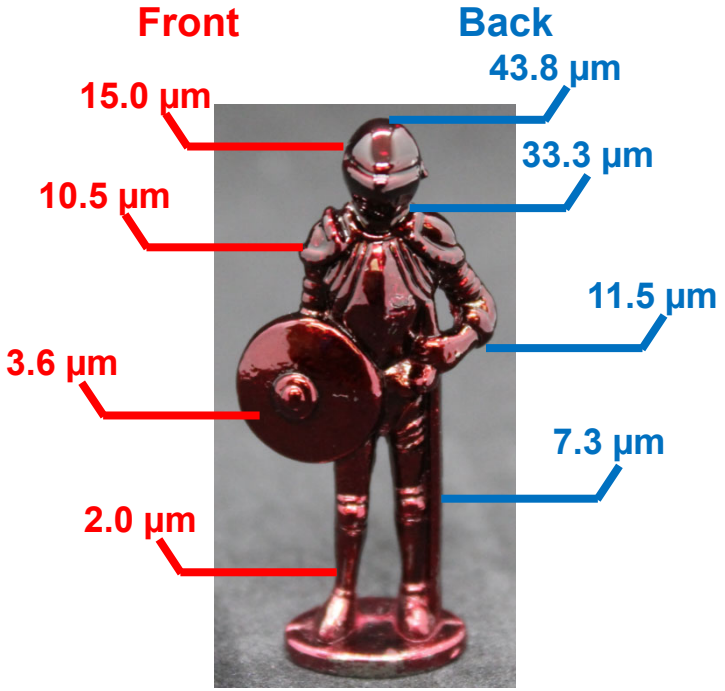
- Focus of our research is processing of

  ceramics and glasses
- For protective coatings
- For encapsulating nanoparticles
- For preparing proton conductors
- ***Melting gels:*** www.youtube.com/watch?v=rgkzfDoaRtk

Prof. Klein Research Highlights

What happens if we spray a conductive surface with an insulator?
"Painting" a Scarlet Knight"
Self-limiting electrospray films on contoured parts
In collaboration with Prof. Singer in Mechanical and Aerospace Engineering

Melting Gel with Red Dye



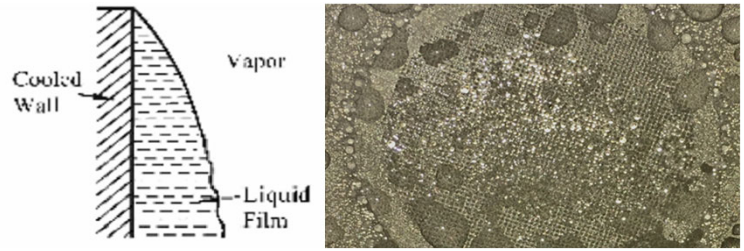
L. Lei, D.A. Koyaceyich, M. P. Nitszche, J. Ryu, K. Al-Marzoki, G. Rodriguez, L. C. Klein, A. Jitianu, J.P. Singer, Obtaining thickness-limited electrospray deposition for 3D coating, ACS Applied Materials & Interfaces, 10, 2018, 11175-11188.

Prof. Klein Research Highlights

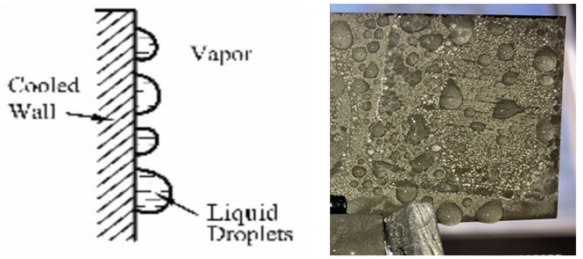
Aresty Project with Sophomore George Wenson

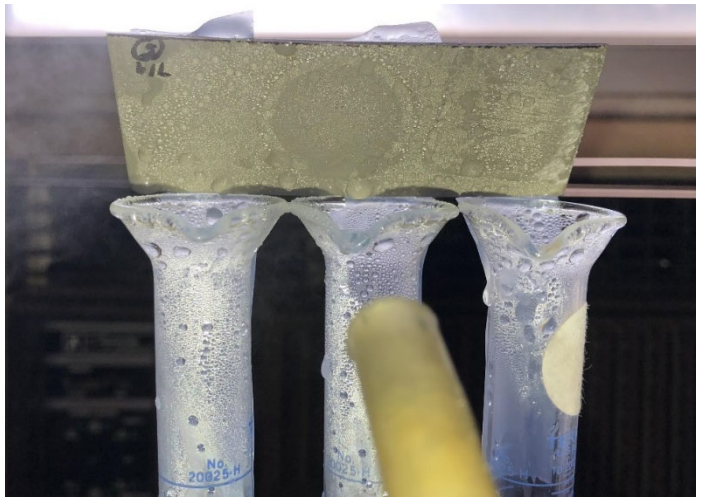
Using the principles of the Cassie-Baxter and Wenzel behavior of water on a sol-gel patterned surface, it was determined that the horizontal line pattern was more effective than either the honeycomb pattern or the smooth surface in collecting water.

"Filmwise" condensation



Dropwise condensation





Prof. Klein Research Highlights

DELLC Project with Katie Lynch
New NSF Grant: INT: Personalized Wearable Metabolic Rate Monitors and Learning Social Networks - A Synergy for Smart Connected Health (SCH)

- With P. Gouma, A. Kiourti, M. Srinivasan (Ohio State University)
- New materials technologies for the non-invasive and non-intrusive monitoring of gaseous biomarkers
- Monitoring skin gases (e.g., acetone)
- Melting gels for packaging

- Gas impermeable
- Flexible
- Transparent
- Applied at room temperature
- Hydrophobic or hydrophilic
- Non-interactive with other components (polymers) in the sensor
- Dielectric insulator
- Non-irritating to skin

National Science Foundation
WHERE DISCOVERIES BEGIN

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Prof. Richard E. Riman

Dept. of Materials Science & Engineering
Rutgers University
riman@rutgers.edu

Materials for Fighting Climate Change

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Prof. Riman Research Highlights

New Processes → New Materials → New Applications

Process Technology

- Low Cost
- Utilizes CO_2
- Reduces CO_2 emissions
- Recyclable

Materials Advantage

- Fire-proof or Fire-resistant
- Lightweight
- Workable meta-material
- Durable

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Prof. Riman Research Highlights

A Process for Inhaling and Exhaling CO_2

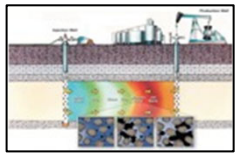

Power Generation


Petroleum Refining


Agriculture


Transportation


Fertilizer


EOR


Beverages


Carbonate Concrete

Inhaling **Exhaling**

$$CO_2 + MM'O_3 \leftrightharpoons MCO_3 + M'O_2 \leftrightharpoons MM'O_3 + CO_2$$

Carbon Capture | Carbon Storage | Carbon Supply

Prof. Riman Research Highlights

The Process is scalable!

Carbonate ceramics for the world of concrete

Precast road beds

Building blocks

- No shrinkage means no cracks or internal stress
- Easier to scale up to large sizes

Solidia Technologies

http://www.solidiatech.com/

Prof. Riman Research Highlights

Pathways to Profitable Growth

RRTC's proven decarbonation technology produces next generation advanced composite materials (ACM's)

High Temperature	Lightweight	Feather-Light	Recyclates
• Basic Refractories • $17B market (2021) • Long service life/recyclable • Lower cost of ownership • TRL = 4 • Mega-t/y CO_2-e impact	• Shipping pallets • $47B Market (2021) • Long service life/recyclable • Low cost of ownership • TRL = 4 • Giga-t/y CO_2-e impact	• Building materials • >$100B (2021) • Structural insulator • Recyclable • TRL = 3 • Giga-t/y CO_2-e impact	• Recycling/CO_2 Supply Chain • $6.1B CO2 Capture (2027) • Cheap, no moving parts • Direct Air & Flue Gas • TRL = 3 • Giga-t/y CO_2-e impact
			

Prof. Ryan B. Sills

μMechanics Of Deformation

microMechanics of Deformation Research Group

Prof. Ryan B. Sills

Department of Materials Science and Engineering

Rutgers University, Piscataway, NJ 08854

ryan.sills@rutgers.edu

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Prof. Sills Scope of Research

What we do…

- We use *advanced computing resources* to study *mechanical behaviors of materials* using *multiscale materials modeling*

Prof. Ryan B. Sills Research Highlights

What we do

- We use *advanced computing resources* to study *mechanical behaviors of materials* using *multiscale materials modeling*

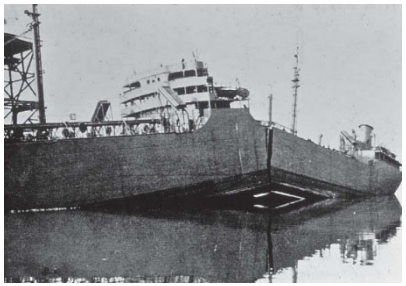
- *Supercomputers* – thousands of CPUs and GPUs networked together
- Enables massively parallel computing (e.g., one task using 100s of CPUs)

Prof. Ryan B. Sills Research Highlights

What we do

- We use *advanced computing resources* to study *mechanical behaviors of materials* using *multiscale materials modeling*

Yield



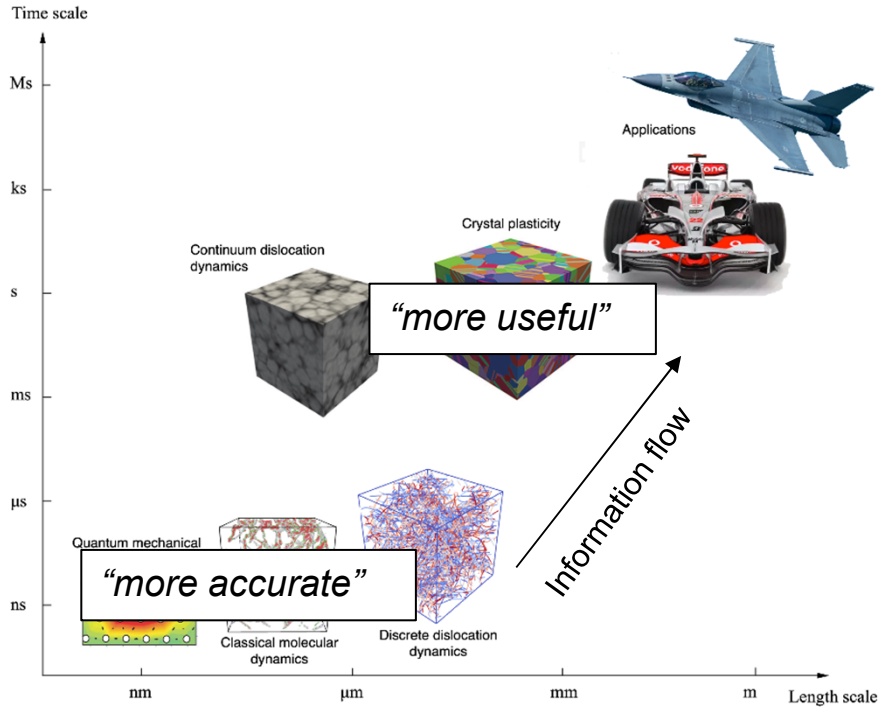
Fracture

Creep

Prof. Ryan B. Sills Research Highlights

What we do

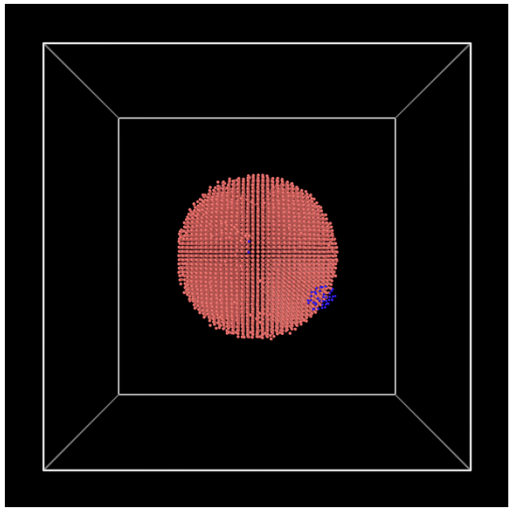
- We use *advanced computing resources* to study *mechanical behaviors of materials* using *multiscale materials modeling*



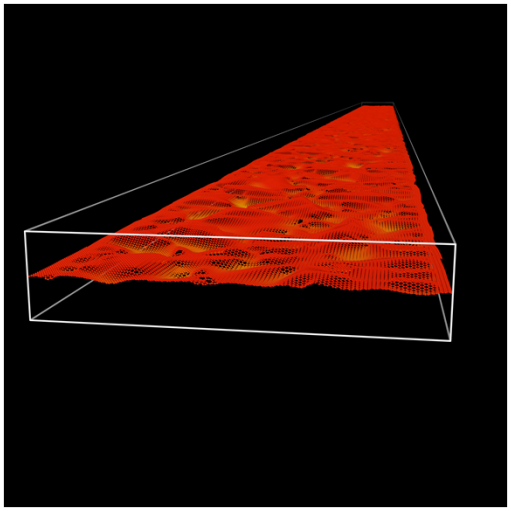
Adapted from Bertin et al., Ann. Rev. Mater. Res. (2020)

Prof. Ryan B. Sills

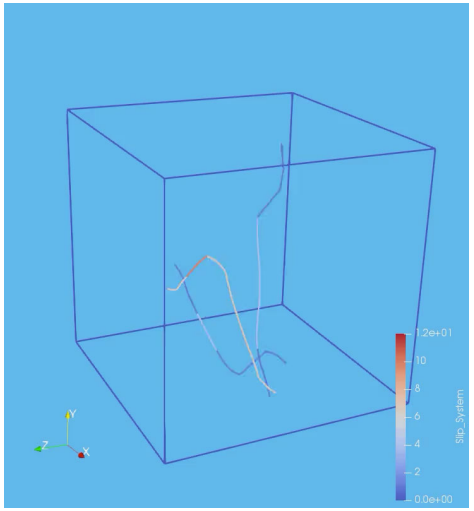
Current Research Projects



Void nucleation during ductile fracture



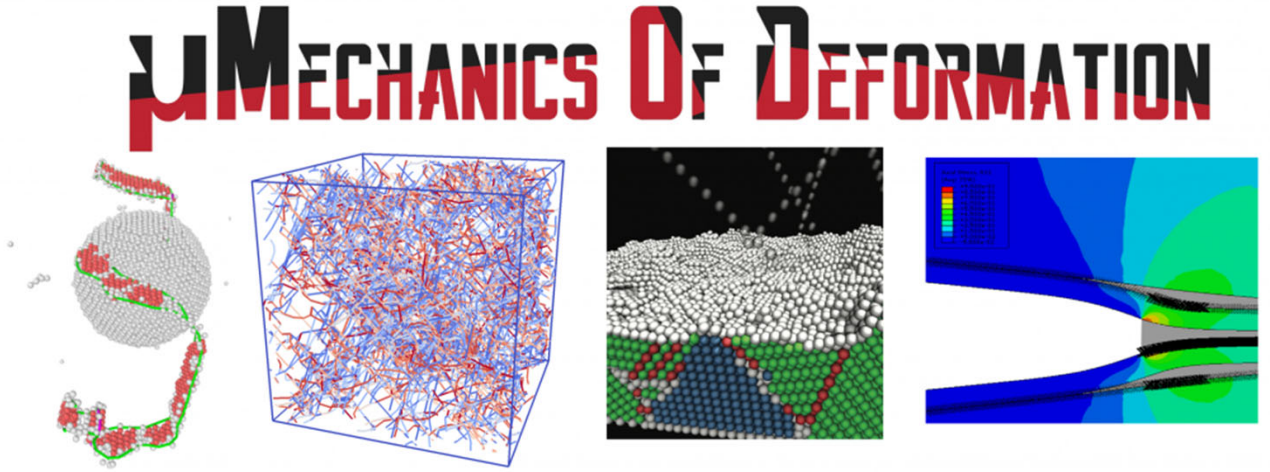
High-rate forming of graphene



Dislocation patterning in deformed metals

Prof. Ryan B. Sills Research Vision

Three overarching goals



1) Micromechanically informed models for engineering predictions
2) Insight for computational design of advanced materials
3) Improved theoretical understanding of mechanical phenomena

You can learn more at mmod.rutgers.edu

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Materials Science & Engineering

A hub for *creativity*, *inventions* & *innovations* to make the world a better place…

Dr. E. Koray Akdoğan (IEEE SrM'05)
Associate Teaching Professor &
Undergraduate Program Director
eka@soe.rutgers.edu

Please visit us @ mse.rutgers.edu or on
Instagram @ rutgers_mse_official_ig
LinkedIn @ linkedin.com/groups/152348/

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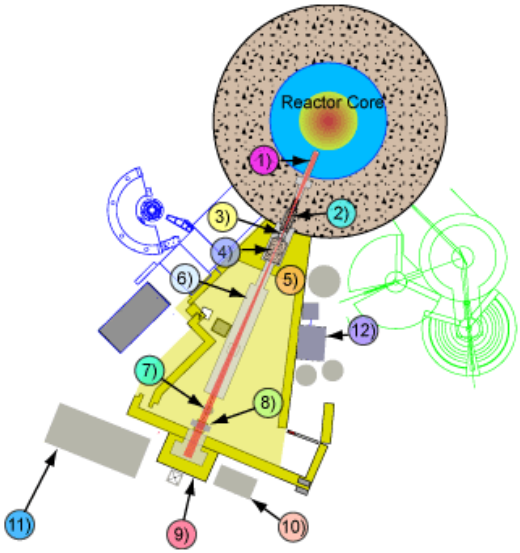
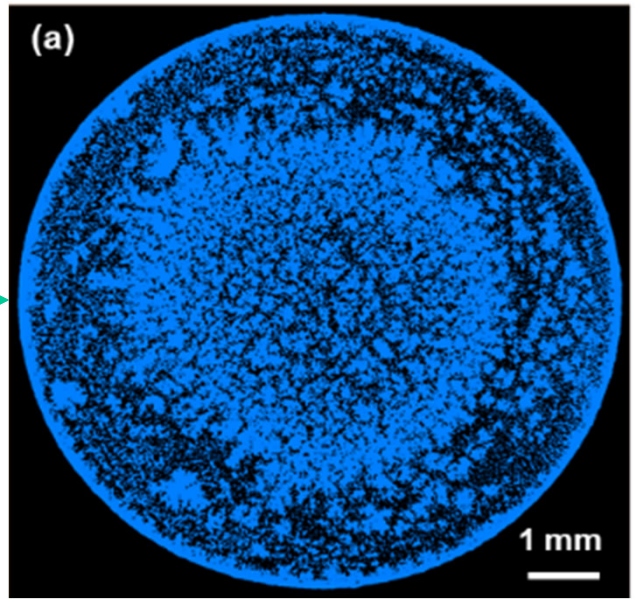
Prof. Akdoğan Research Highlight: Binder Removal from Ceramic Preforms in Additive Manufacturing (3D Printing)

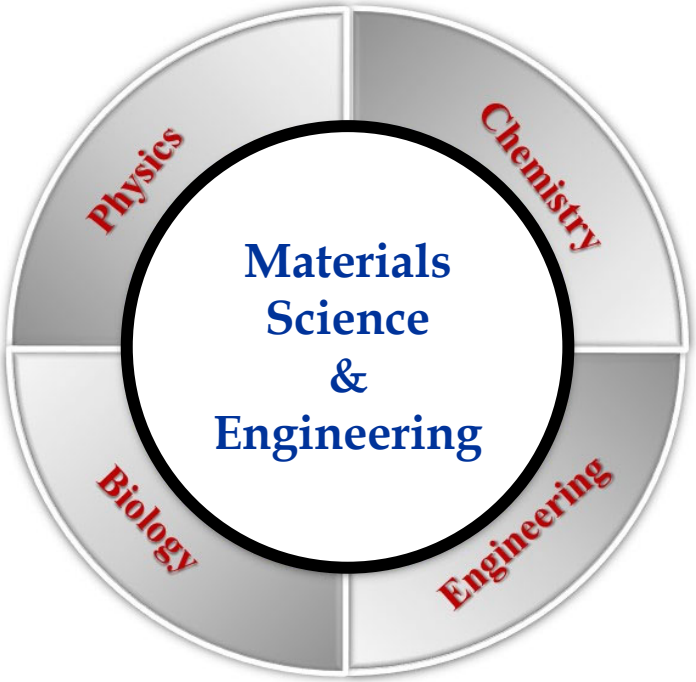


1) Neutrons from reactor
2) Tapered colimation
3) Bismuth filter
4) Rotating Drum
5) Wax and shot filled shields
6) Evacuated flight tube
7) Sample position
8) Neutron camera
9) Beam stop
10) Small fuel cell test stand
11) Large fuel cell test stand
12) Hydrogen generator

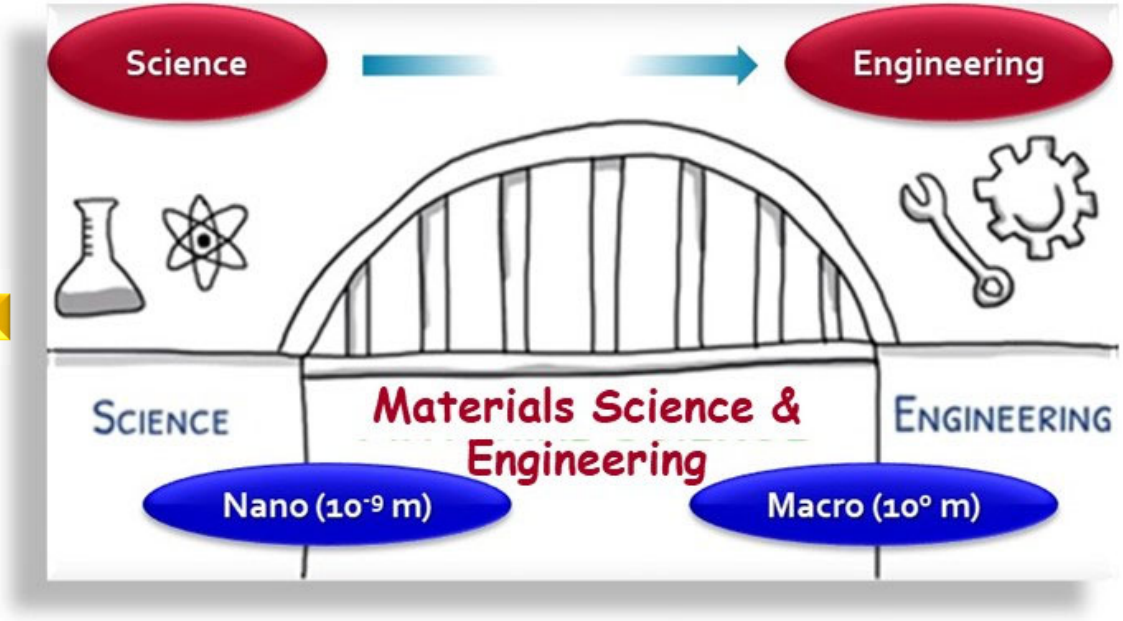


Higher resolution imaging with neutrons to assess the hydrogen migration as a function of T and t ongoing…image processing intensive work (E. McAleer, PhD thesis)

What is Materials Science & Engineering (MSE)?



- A highly multidisciplinary & unique field in engineering that focuses on developing and producing engineering materials through atomic, molecular, nano-, and microscopic level design and processing.



- MSE is the bridge between the fundamental sciences and all other engineering disciplines…

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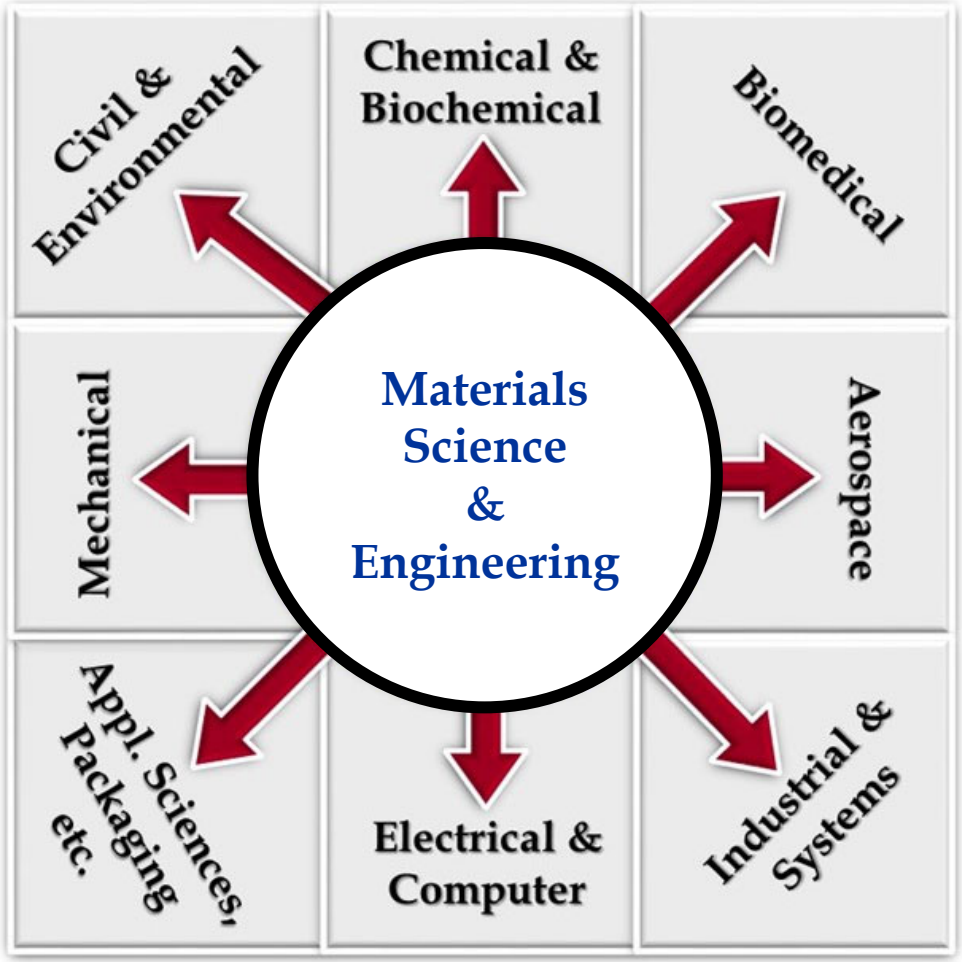
Why is Materials Science & Engineering Unique?



- All engineering disciplines need advanced materials with novel properties & functionality.
- Advances in all engineering disciplines depend upon the inventions and innovations in Materials Science & Engineering.
- MSE inherently plays a central role in engineering as it is an enabler of technological advances and innovations in all engineering disciplines.

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Broader Impact of MSE in the 21st Century

20th Century	21st Century
❑ Metals	❑ Nanostructured
❑ Polymers	❑ Functionalized
❑ Ceramics	❑ Self-assembling
❑ Semiconductors	❑ Self-healing
❑ Composites	❑ Smart

High demand for novel materials will always be there since no advances in engineering are possible without new materials.

Very good employment opportunities for MSE graduates will continue .

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What to expect when you join Rutgers MSE?

- Approximately 30 students per class
- 16 Faculty offering courses & research in all areas of MSE
  - Nanotechnology
  - Polymers
  - Biomaterials
  - Metals
  - Glass Engineering
  - Ceramics Engineering
  - Cement and concrete
  - Energy storage & batteries
  - Armor materials
  - Modeling and simulation
- Work directly with faculty on projects in the lab with 1-to-1 mentoring.

- Active and hands-on learning through laboratory and project intensive curriculum.
- Multiple Capstone Project options enabling you a running-start in your careers.

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Who hires our graduates?

Companies in blue fonts denote Fortune 500 Companies!

US Army Picattiny Arsenal
US Army Fort Monmouth
Navy Earle
Navy Lakehurst
Raytheon
Colgate Palmolive
Ceramic Magnetics
Morgan Advanced Materials
Certech (Morgan)
Howmet
HED International
GAF
Johnson and Johnson
Colgate Palmolive
Honeywell
Niagara Conservation
Tiffany and Co
Lucent Alcatel
Ceramco
MicroStamping
Ferro

Degussa
Wheaton Glass
Tyco
Advanced Cerametrics
Dentsply
IBM
Lockheed
Becton Dickenson
BASF
Telcordia
Foster Wheeler
KPMG
Avaya
Sarnoff
Physical Acoustics
Transistor Devices Inc
Loreal
Merck
Schering Plough
Aventis
NEC

PSE&G
General Dynamics
MTS
Phillips Xray
Bristol Myers Squibb
Siemens
Osteotech
ISP
3M
DuPont
Millennium Cell
Axion
Lamina
Agere
Integrated Photonics
In Plane Photonics
NEI
Coherent
SMI
DMI

Ceramare
MEI
Minteq
Phillips
American Standard
Dept 56 Lawrenceville
Fiberguide Industries
Potter Industies
Shamrock Technologies
Isowave
Sensor Unlimited
Epitaxx
PDLD, Ewing
Universal Displays
Exxon-Mobil
Hess

You can also find our graduates in coveted jobs across the US in private companies, industrial R & D labs, defense industry, government labs, Silicon Valley etc. They are highly sought after…

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For more information about Rutgers MSE

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Program Director
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Questions?

- https://mse.rutgers.edu/
- **Materials Science Demo:** https://youtu.be/VPJ1Fg5OpNs