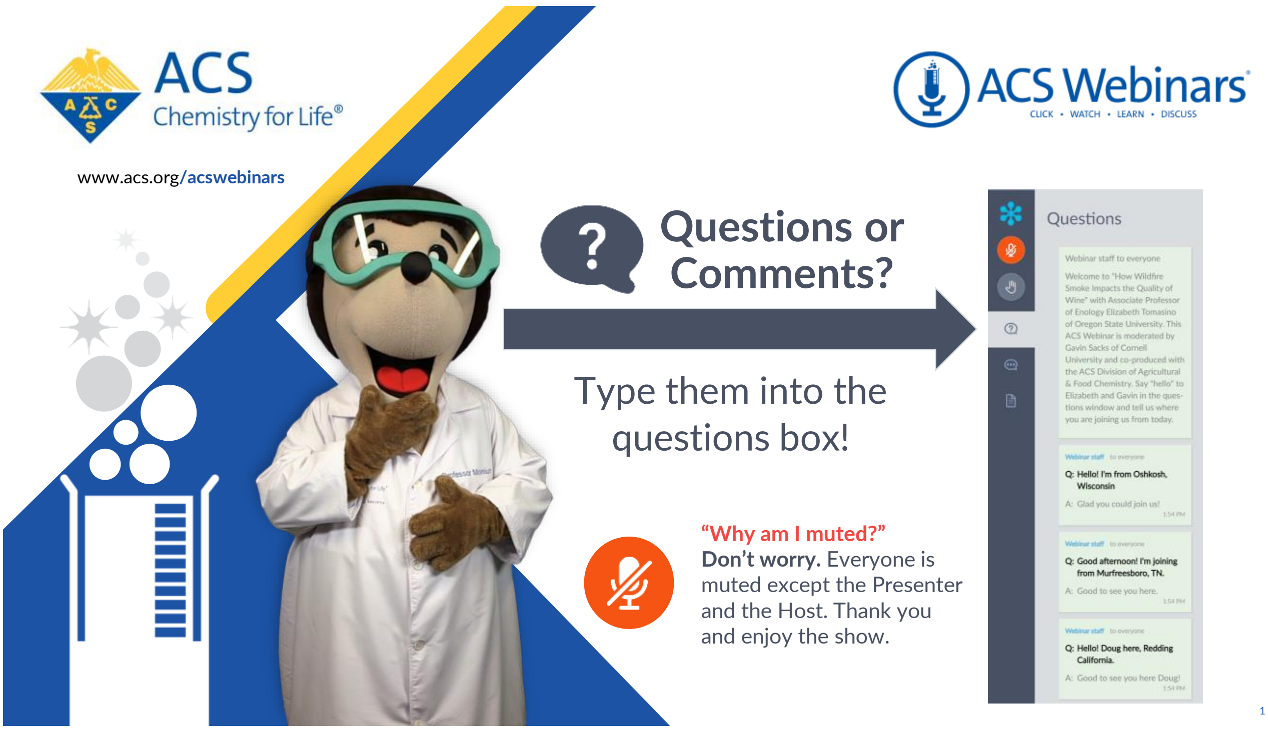
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Questions
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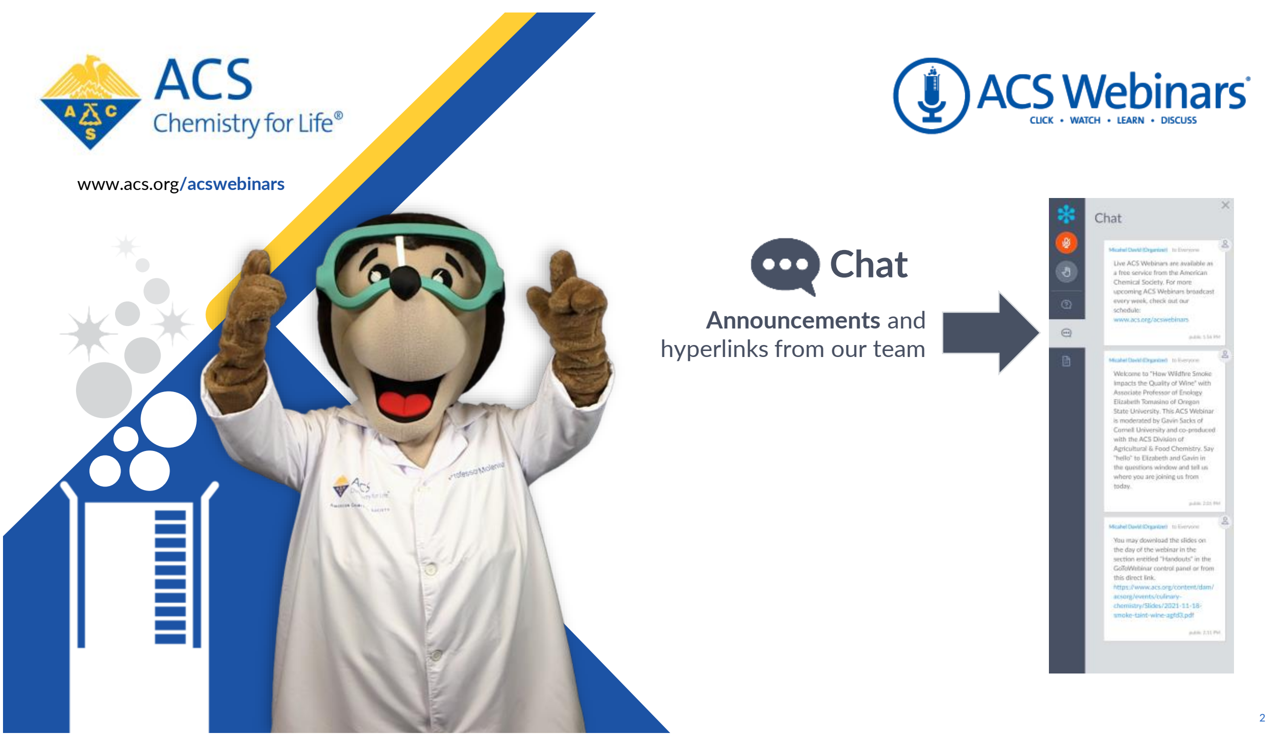
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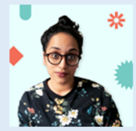
Science Writer & Exec Producer



Deboki Chakravarti, PhD
Science Writer & Co-Host

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Career Consultant Directory

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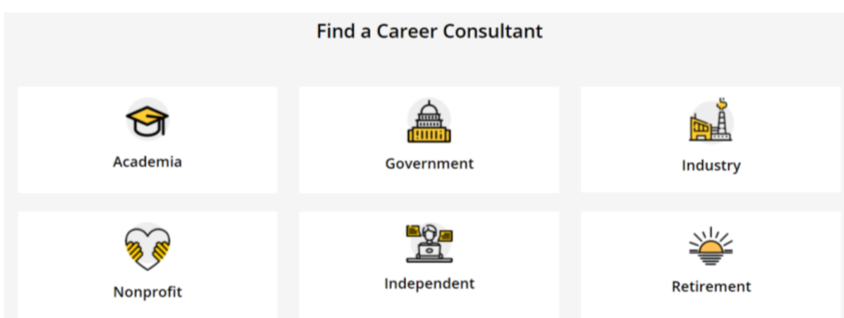

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ACS Scholar Adunoluwa Obisesan

BS, Massachusetts Institute of Technology, June 2021
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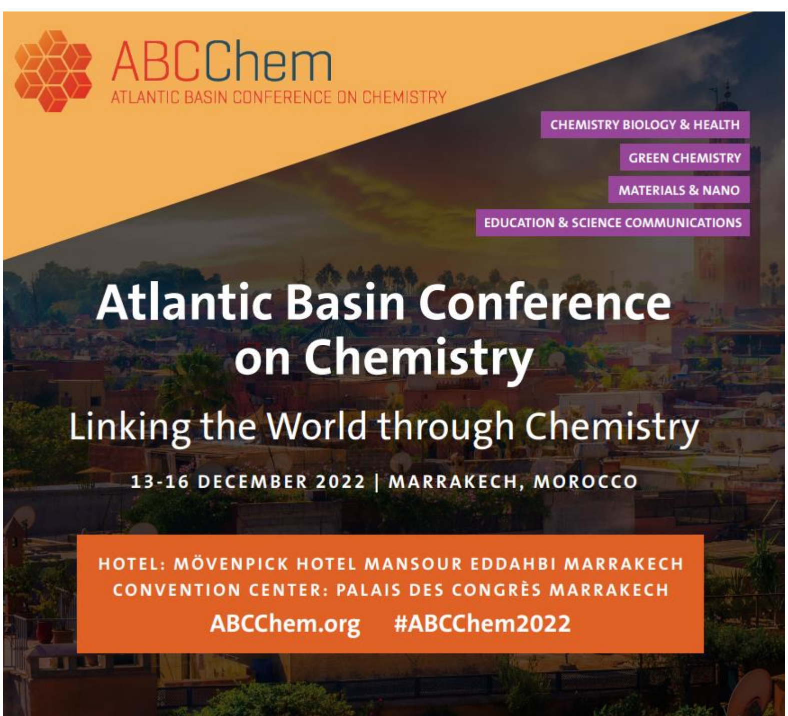

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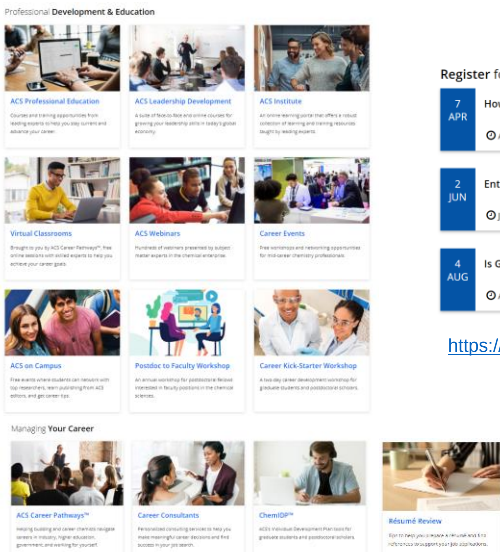

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2 JUN	Entrepreneurship June 2, 2022	7 JUL	Networking July 7, 2022
4 AUG	Is Grad School Right for Me? August 4, 2022	1 SEP	Leadership and Soft Skills Development – What You Need to Advance in Your Career September 1, 2022

https://www.acs.org/content/acs/en/careers/personal-career-consulting.html

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https://fs7.formsite.com/acsdiversity/ACSMemberFeedback/index.html

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- 1st Year Free Membership!
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- Industrial scientist support and networking through IAB (Industrial Advisory Board)
- Polymer science-related conferences and workshops advertised through the POLY list serve
- Online educational webinar and webshop series covering cutting-edge polymer research
- Opportunity to vote for the executive committee (annually)
- Recognition for membership (5th, 10th, 20th, and 30th anniversaries)
- Student support – student awards, student symposia, career panels at ACS meetings, support for student chapters.
- An excellent support group for building strong networks in the polymer community!

https://polyacs.org

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How Polymeric Materials Protect Our Armed Forces

JOSEPH L. LENHART, PhD
Chief, Polymers Branch, Weapons and Materials Research Directorate, DEVCOM Army Research Laboratory

DAVIDE SIMONE, PhD
Senior Research Chemist, Air Force Research Laboratory

Peter Zarras, PhD
Research Chemist, Naval Air Warfare Center Weapons Division

This ACS Webinar® is co-produced with the ACS Division of Polymer Chemistry.

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U.S. ARMY

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U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND –ARMY RESEARCH LABORATORY

Polymeric Materials for Army Applications

Joseph L. Lenhart
Chief, Polymers Branch
Weapons and Materials Research Army Research Laboratory
Aberdeen Proving Ground, MD

ACS Webinar
June 15, 2022

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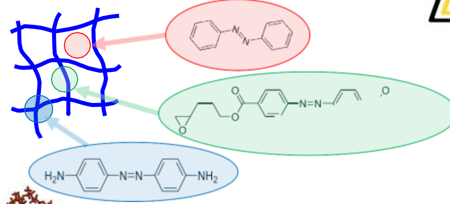
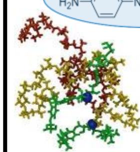
ARL / ABERDEEN PROVING GROUND (APG)





Fun life stuff
- Centrally located
- On the Chesapeake Bay
- Cultural, sports, outdoor activities

Fun work stuff
- Chemistry to processing
- Proto-type development
- Full-scale assessment

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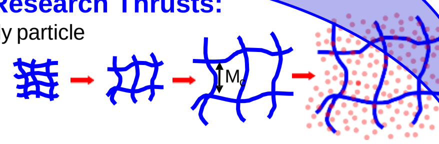
POLYMERS BRANCH OVERVIEW

Current State:
- ~20 staff
- Skilled workforce (PhD)

Overarching Polymer Expertise:
- **Physics** – structure / property relations (mechanics and functional)
- **Synthesis** – new materials through chemistry and additives
- **Processing** – new materials through chemistry and structural control
- **Modeling** – insight and guidance (quantum, molecular, meso-scales)

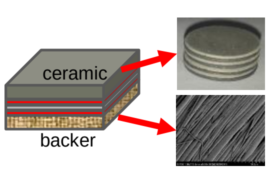
Underpinning Research Thrusts:

1. **Polymer Processing:** semi-crystalline, highly particle loaded, multi-material, new feedstock



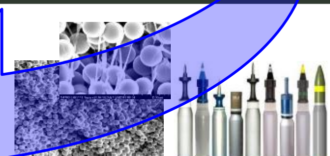
2. **Resins / Adhesives:** fiber and particle loaded composites, complex laminate structures, dynamically responsive feedstock

Targeted Applications:



Soldier Protection:
Body armor, signature management

Vehicle Protection:
Complex laminates, novel mechanisms



Long Range Weapons:
Small and large caliber munitions, propellants, survivability, range, lethality

20

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Audience Survey Question

ANSWER THE QUESTION ON THE INTERACTIVE SCREEN IN ONE MOMENT

Have you considered a defense laboratory as a career option?

- Yes, I already work for a defense laboratory
- Yes, I am very interested
- I knew it was an option, but did not consider it
- I never knew it was an option

* If your answer differs greatly from the choices above **tell us in the chat!**

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POLYMERS FOR THE DISMOUNTED SOLDIER

Protective Equipment
- Body armor
- Helmet
- Fabrics for extremity / groin protection
- Eye protection

Lethality
- Small caliber weapons
- Ammunition
- Grenades

Soldier carries 70 to 130 lbs depending on their job, mission type, and mission duration

Electronics
- Night vision
- Optics
- Radio
- Batteries

Uniform
- Camouflage – visibility
- Thermal management
- Boots / pads

- Armor 25-30 lbs
- Helmet 4-5 lbs
- Gun 6 - 25 lbs
- Ammunition 7-30 lbs
- Batteries 5-20 lbs
- Water 10-15 lbs
- Uniform, ruck sack, boots, glasses, light, radio, food, grenades, shovel, first aid, ….

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POLYMERS FOR GROUND VEHICLES

Lethality systems
- Large, medium, and small caliber munitions
- Missiles
- Lightweight composites
- Propellants

Structural systems
- Historically metallic
- Opportunities for structural composites laminates
- Composite track pads

Protection systems
- Passive protection
- Active protection
- Laminate composite armors packages
- Transparent armors
- Coatings – chemical protection and visibility control

Electronics systems
- Ruggedization
- Sensor and electronics protection
- Packaging

1. **Many types of ground vehicles:** tracked vehicles (Abrams Bradley); Wheeled (Stryker, Humvee, transport vehicles)
2. **Opportunities:** Unmanned systems for fighting and resupply

CHALLENGE OF EXTREME ENVIRONMENTS

1. ***Environmental Durability***
   - Temperature
   - Humidity
   - Life-time
   - Fuel, solvent, dirt, mud
   - Chem / Bio / Radiological
   - Electrical, optical, …
   - Cycling
2. ***Mechanical extremes***
   - Quasi-static, impact, ballistic, blast strain rates
   - High pressure
   - Launch conditions

Strain Rate: Humans — Cars — Airplanes — Bullets

10^{-4} s^{-1} — 10^{0} s^{-1}: **Quasistatic Testing**

10^{0} s^{-1} — 10^{2} s^{-1}: **Standard Impact Tests**

10^{4} s^{-1} — 10^{6} s^{-1}: **Ballistic Testing**

- ***Complex composites and structures are critical***
- Understanding deformation / failure processes for both the individual materials and the composites is critical

POLYMERS RESEARCH RESINS

Introduction to Polymers Research for Vehicle and Soldier Protection Applications:

1) Resins and adhesives

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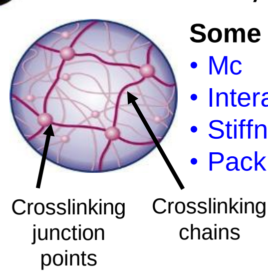
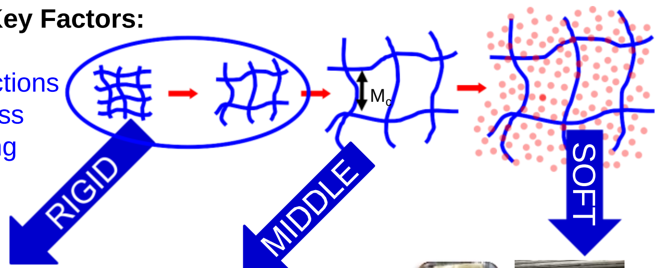
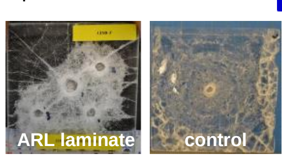
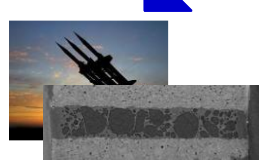
POLYMER NETWORKS: FUNDAMENTAL AND APPLIED RESEARCH

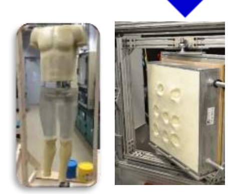


Some Key Factors:
- Mc
- Interactions
- Stiffness
- Packing









Armor (Vehicles, Rotorcraft, Body Armor):
- 30% weight savings for glass based transparent armor
- Transparent and non-transparent

Armor Durability:
- Processing protocols
- Materials solutions

Weapons:
- Propellant coatings for temperature compensation
- Insensitive munitions
- Structured propellants

Vehicles:
- Fuel hose and storage
- Fuel tank ballistic / fire protection

Protection Assessment:
- ARL Room Temperature Insensitive Clay (ARTIC)
- Environmentally stable gel for assessment of Pelvic Protection System
- Anthropomorphic forms

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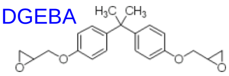
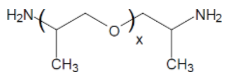
IMPACT TESTING WITH MODEL SPHERICAL BB: IMPORTANCE OF GLASS TRANSITION

Knorr DB, et al, *Polymer*, **53**, 5917 (2012)

DGEBA

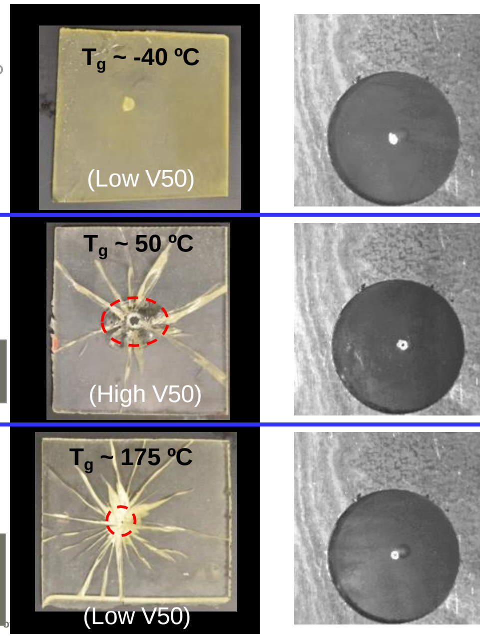


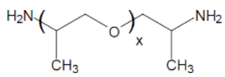
D2000 x=33



DGEBA/ D-2000

Shear plug failure (rubber)

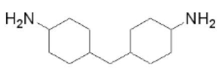




DGEBA/ D-400

D400 x=6.5

Extensive spall zone
Small radial cracking (low Tg glass)



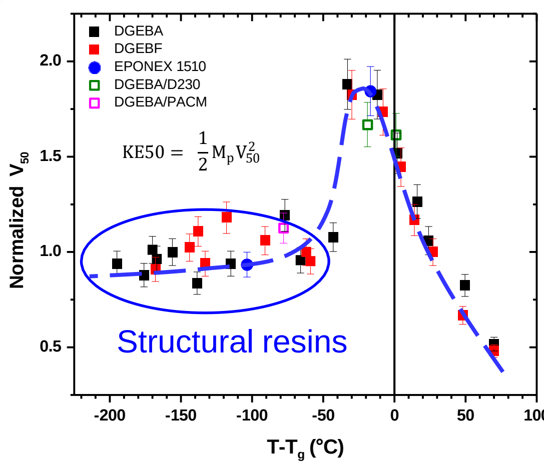
PACM

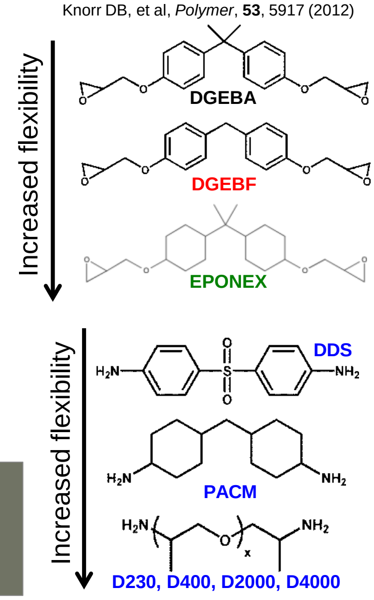
DGEBA/ PACM

Small spall zone
Extensive radial cracking (high Tg glass)

SEGMENTAL RELAXATIONS NEAR T_G ARE CRITICAL FOR IMPACT PERFORMANCE

Knorr DB, et al, *Polymer*, **53**, 5917 (2012)



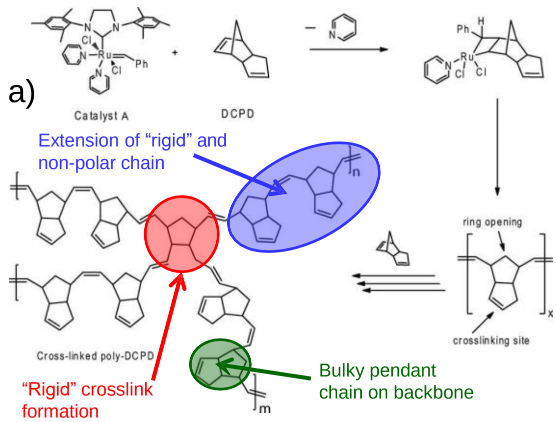


- Impact temperature relative to Tg is dominant factor in epoxy network ballistic response
- Temperature dependent response correlates with Vogel Temperature

ROMP RESINS FOR STRUCTURAL PERFORMANCE AND TOUGHNESS

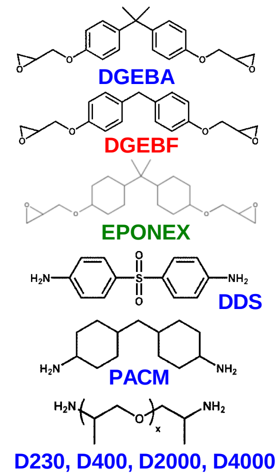
Ring Opening Metathesis Polymerization (ROMP)

a)



Simons R., *J Polymer Science A: Polymer Chemistry*, ***50***, 89 (2012)

b)



1. Weak chain-chain interactions and high Mc provides ductility
2. Stiff junction points and chains enable higher Tg

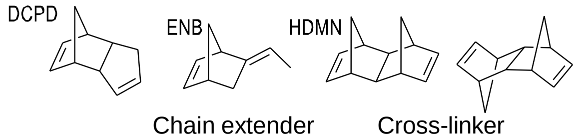
UNIQUE BALLISTIC FAILURE FOR P-DCPD COMPARED TO GLASSY EPOXIES

Knorr DB, et al, *Comp. Sci. Technol.*, **114**, 17 (2016)

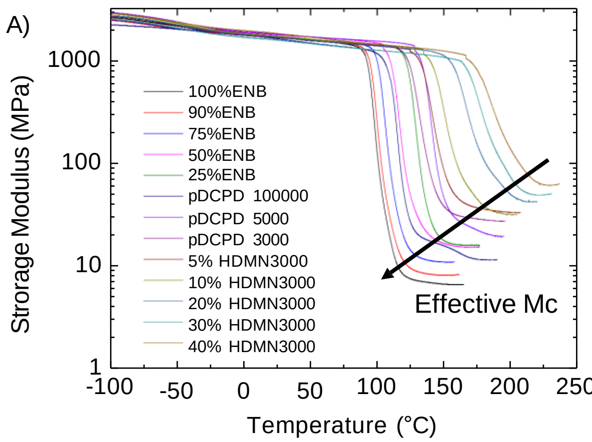
Bain ED, et al, *J. Mater. Sci*, **51**, 2347 (2016)

pDCPD exhibits a ductile like failure during ballistic impact with no large scale radial fracture

CONTROLLED CROSSLINK DENSITY



TR Long, et al, *Soft Matter*, **14**, 3344 (2018)



Control effective crosslink density and T_g with co-monomer content

$$M_{C,a} = \frac{3\rho RT}{E'_r}$$

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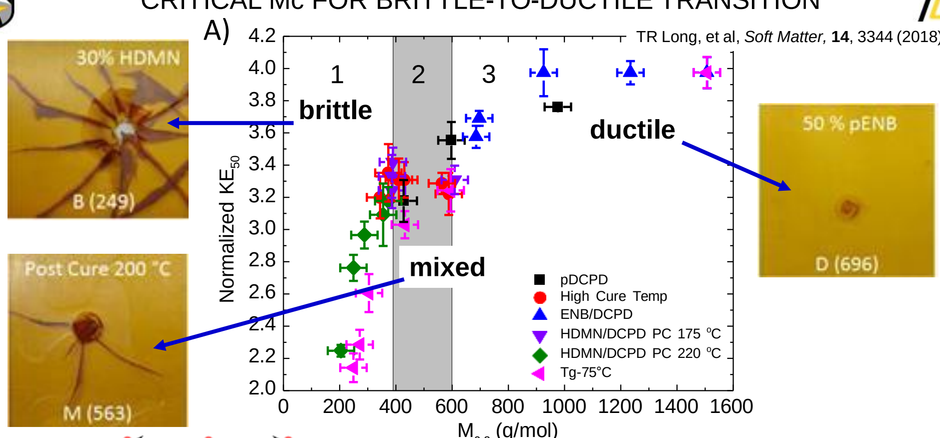
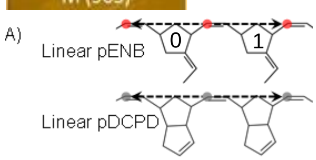
CRITICAL Mc FOR BRITTLE-TO-DUCTILE TRANSITION

TR Long, et al, *Soft Matter*, **14**, 3344 (2018)





- Critical effective Mc (400-600 g/mole, 6 units)
- As Mc effective approaches persistence length resin becomes brittle (lose orientational correlation around 6 monomeric units)

Series of ROMP resins with: a) no radial fracture; **b)** Tg 120-145°C; **c)** 3.5-4X impact resistance relative to structural epoxy with similar Tg

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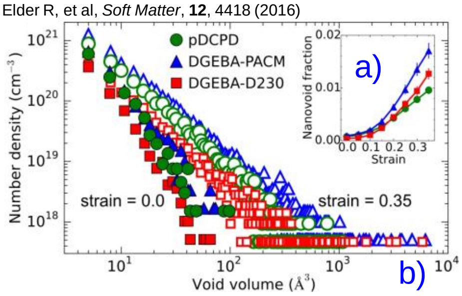
MOLECULAR DYNAMICS INSIGHT INTO pDCPD TOUGHNESS

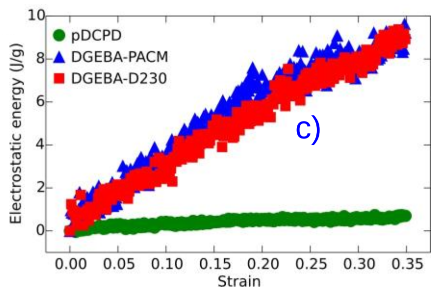
Knorr DB, et al, *Comp. Sci. Technol.*, **114**, 17 (2016)
Elder R, et al, *Soft Matter*, **12**, 4418 (2016)

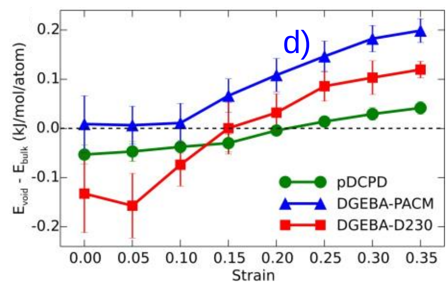


RM Elder, et al, *Soft Matter* **14**, 8895 (2018)

1) Polar epoxy void formation is energetically unfavorable. Non-polar ROMP void formation is energetically neutral
2) Atomic fluctuations (relaxation processes) are faster around voids than in bulk
3) Atomic fluctuations are suppressed with increasing crosslink density and polarity

- ROMP resins are more tolerant to formation of molecular voids during deformation
- Increasing crosslink density and polarity suppresses local relaxations around the voids





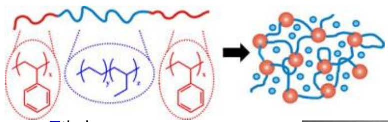
POLYMERS RESEARCH RESINS

Introduction to Polymers Research for Vehicle and Soldier Protection Applications:

2) Polymer gels

POLYMER GELS FOR TISSUE SIMULANTS

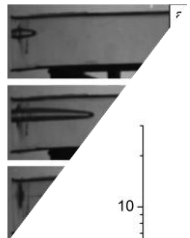
SEBS:



Styrene

Ethylene-co-Butylene

Styrene



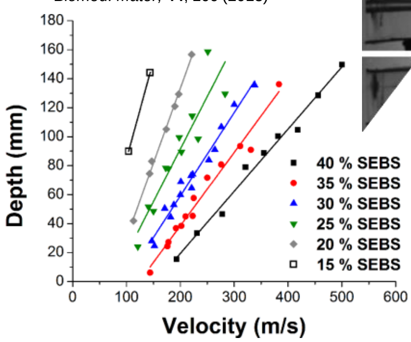
Density difference between projectile and gel

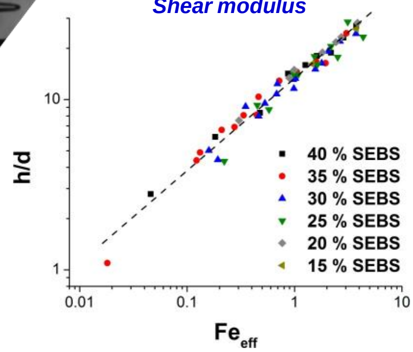
Velocity after penetration

$$Fe_{eff} = \frac{(\rho_s - \rho_f)v_{eff}^2}{G}$$

Shear modulus

RA Mrozek, et al, *J. Mech. Behav.. Biomed. Mater,* **44**, 109 (2015)

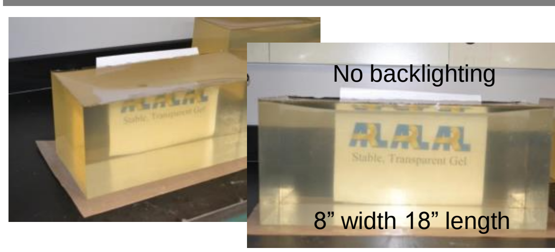




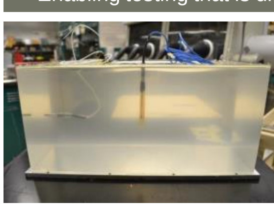
- **Need:** Tissue "simulants" to evaluate blast / ballistic effects
- Tunable modulus, toughness, and ballistic penetration depth

POLYMER GELS FOR TISSUE SIMULANTS

Use gel for unique testing protocols that require long times in outdoor ranges



- Material has better time, temperature, humidity stability than ordinance gelatin
- Enabling testing that is difficult with ballistic gelatin



Instrumented gels

Summertime testing

Pelvic Protection System (PPS) evaluation

POLYMERS RESEARCH PROCESSING

Introduction to Polymers Research for Vehicle and Soldier Protection Applications:

3) Thermoplastic processing (~7000 ft^2 of processing laboratories)
   a) Processing as tool to make new materials (chemistry and structure in-situ)
   b) Facilitate transition by enabling scale-up for engineering evaluations (coupon to pilot scale)
   c) Engineering controls for safe and reproducible processing (clean rooms)

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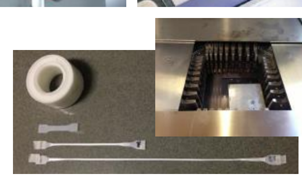
COMPOUNDING AND COUPON PREPARATION LABORATORY (CLEANROOM)

Compounding / Mixing

- Capability from grams to 100 Kg/hr (11, 16, 24, 35 mm twin screws)
- Up to 52 L/D
- Heated, cooled, high shear / torque



Fiber, filament, tape processing

- Single screw extruders
- Coupon scale continuous (1- 6 inch width)
- Uni- and bi-axial stretching

Safety and room design

- Powder handling laminar flow hoods
- Ionizers / stainless steel - static control
- Temperature and humidity control
- Emergency exhaust

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FIBER AND FILM PROCESSING LAB (CLEANROOM)

Tape processing
- 5 layer cast film line
- Multi-layer forced assembly co-extrusion processing (MLFACE)

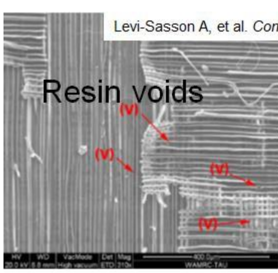
Tape rolling, drawing, and high pressure lamination
- Machine direction orientation on cast film line
- High pressure roll mill

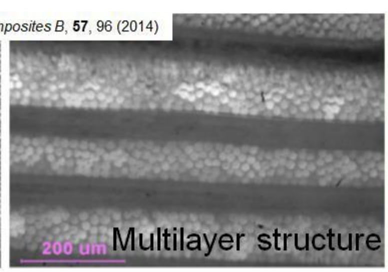
Fiber and filament processing
- Water or air cooling
- Single or bi-component
- Flexible dies and drawing

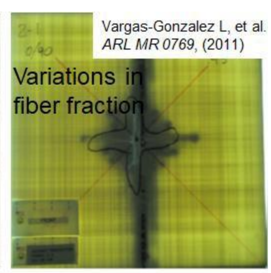
We can use COTS or in-house developed formulations from twin screw extruders

HOW DO WE USE FIBERS AND FILMS IN BALLISTIC COMPOSITES

SOA: UHMWPE and Kevlar-based composites arranged in a 0 – 90 configuration







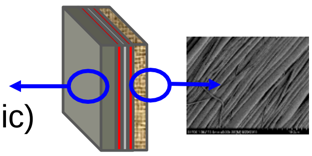
Limitations with current composites:
- Fibers are macro-scale
- Resin starved composite with voids
- Poor mechanical binder (~ 15% parasitic)
- Poorly designed binder-fiber interface
- Solvent heavy fiber processing is high cost

What we would like
- Fine scale fibers – near theoretical
- Intimate binder-reinforcement contact
- Tough binder with lower content
- Designed interface
- Low or solvent-less process

Gap: Manufacturing strategy to enable all of these improvements

WHAT ARE WE TRYING TO DO?

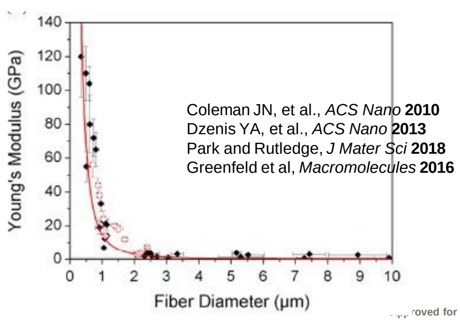
Strike face
(metal or ceramic)

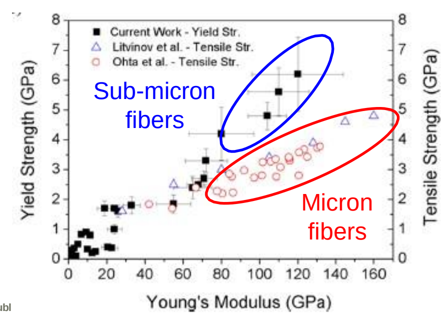


Polymeric Fiber

Concept: 1) Fine scale (sub-micron) fibers and films are stiffer and stronger than macro-scale; **2)** quality binder and interface will enhance performance

Gap: Cost effective continuous manufacturing





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MULTILAYER FORCED ASSEMBLY CO-EXTRUSION (MLFACE) COLLABORATION WITH CWRU – PEAK NANO

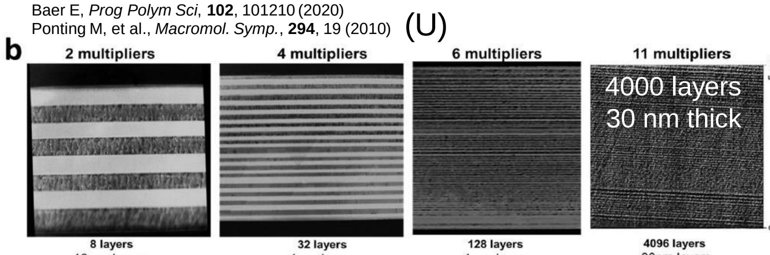
- ✓ Tapes with fine scale reinforcement structure (sub 100 nm dimensions)
- ✓ Intimate binder content due to co-extrusion process
- ✓ Suitable for melt or gel casting operations (cost and performance)

Courtesy of Dr. Ponting at PeakNano

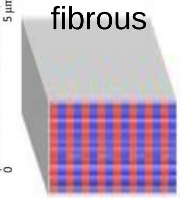
peak nano | CASE WESTERN RESERVE UNIVERSITY

Gary Wnek
Eric Baer
Mike Ponting

Baer E, *Prog Polym Sci*, **102**, 101210 (2020)
Ponting M, et al., *Macromol. Symp.*, **294**, 19 (2010) (U)



Layered or fibrous



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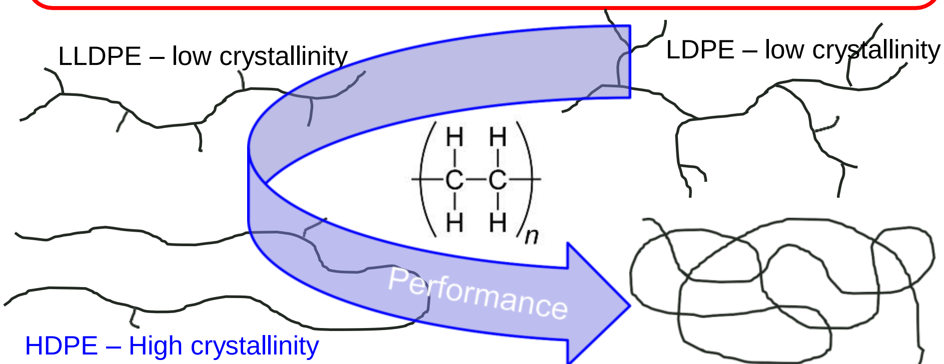
WHAT DO WE NEED TO DO TO MAKE MLFACE WORK FOR ARMY?

TASK 1: Feedstock for high performance MLFACE tapes
- Reinforcement phase: HDPE and HDPE/UHMWPE blends
- Binder phase: PE copolymers (co-crystallize at interface)
- Temperature and shear dependent viscosity



HDPE – High crystallinity
Mw ~ 80K – 500K (Entanglement)
Melt processable

UHMWPE – High crystallinity
Mw ~ 500K – 12,000K (highly entangled) Gel spinning

Identified highly linear PE feedstock

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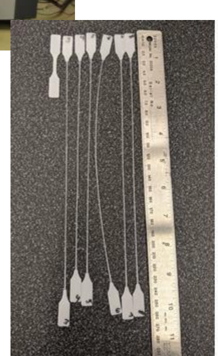
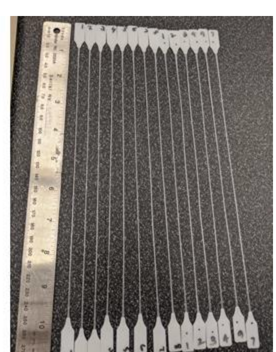
TASK 1: HDPE PROCESSING DEVELOPMENT AND PERFORMANCE ASSESSMENT

- Extrude 6 inch wide tapes
- Cut out dog-bones
- Draw with controlled rate and temperature

✓ Draw coupons 20-40X
✓ 40-60 GPa modulus
✓ 600-900 MPa strength (lower than we expected)
✓ Feedstock and properties are OK but not great





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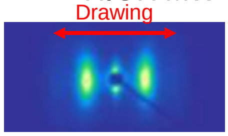
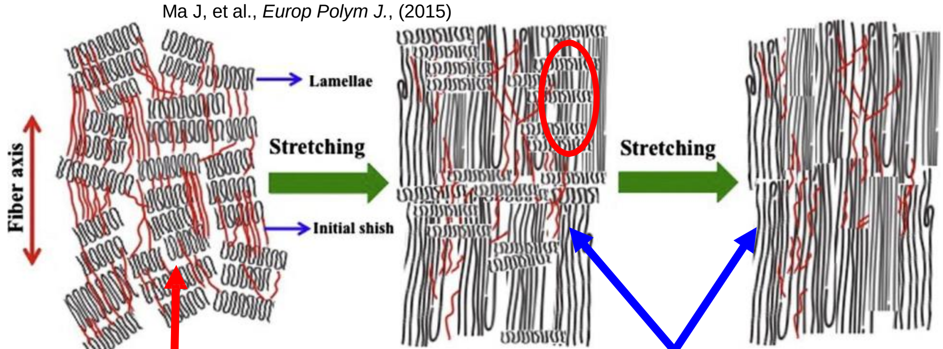
IMPROVING FEEDSTOCK PERFORMANCE: HIGH MW TAIL



- Scattering shows that we are orienting lamella and increasing crystallinity
- Not forming extended chain crystals

Ma J, et al., *Europ Polym J.*, (2015)



We are here (increasing lamellae organization with draw)

Solution: Blend UHMWPE to create "shish" to get here

Hsaio *Polymer*, 2005 46(10), 8587

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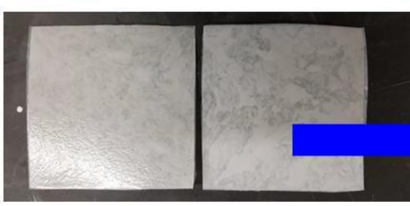
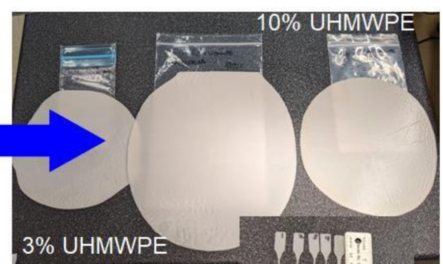
TASK 1: IMPROVING FEEDSTOCK PERFORMANCE: HDPE / UHMWPE BLENDS





Mixing temperature, residence time, screw design on twin screw extruders

Initial Sheets:
- HDPE and UHMWPE poorly mixed
- Low draw ratio and poor performance

Recent Films:
- Higher quality and drawable blends
- Measuring performance / structure

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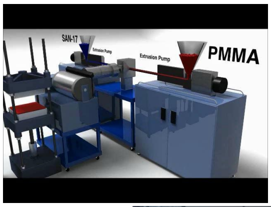
TASK 3: INITIAL DRAWING AND MECHANICS OF MLFACE FILMS



- Successfully MLFACE processing with our feedstock materials
- Numerous multipliers to get pre-drawn fiber and tapes with ~ micron dimensions

- Initial tape drawing with 20% binder
- Good mechanics but still need to improve
- Semi-continuous structure

1. Challenges with tape uniformity
2. Refining feedstock
3. Moving to larger processing systems for compounding (52 L/D) and tape casting (better processing controls)
4. Good progress – long way to go

LONG TERM RESEARCH OPPORTUNITIES?

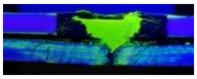
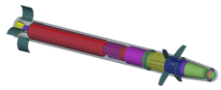
Long term research opportunities for ARL – academic – industry partnership in polymers

- Higher risk, longer term, more labor than ARL can invest in by itself

1) Dynamically responsive rigid systems
2) Complex multi-material processing

WHY DYNAMICALLY RESPONSIVE POLYMERS

JM Dennis, et al, *Polym. Internat.*, **70**, 720 (2021)

microsecond millisecond second

Response Times

1's 10's 100's 1000's

Cycles

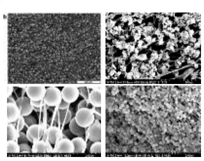
Magnitude of Change

Challenge: Broad range of potential performance parameters that are dependent on the applications

Objective: Map out this space. What is possible under what conditions?

Major Gap: Dynamic response in rigid systems

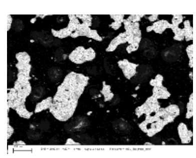
CHALLENGES TO THE LAYERED MATERIALS AND STRUCTURES COMMUNITY



Particle loaded multi-layers
- Near jamming limit (50+ vol%)
- Continuous processing
- Controlled porosity
- Complex form factors

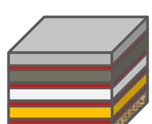

Automated design
- Robotic assisted materials design
- Automated composite assembly
- Complex multi-material structures
- AI/ML integrated manufacturing

Multi-material processing
- Adapted to other materials
- Co-processing of metals ceramics, polymers
- In-situ interfacial control
- Down-stream drawing / shear deformation to refine and align microstructures



Bradley, et al, Nature Chemistry, 11, 578 (2019)

Thick multi-materials composites
- Interfacial control
- Curved and complex shapes
- High pressure consolidation


Processing directed cellular assembly
- Synthetic Biology and Cellular synthesis
- Polymer processing of cellular structures

TAKE HOME MESSAGES / AUDIENCE QUESTIONS

1. ARL is great place to work and live
2. Work on fundamental and applied programs
3. Excellent facilities for chemistry, processing, analysis, and engineering evaluation
4. Polymeric materials are important for Army systems: soldier, vehicles, weapons

- Are you interested in working or collaborating with ARL?
- Needs: Generically in polymer science
- Specifically: processing, mechanics
- BS-PhD

Contact me at: joseph.l.lenhart.civ@army.mil

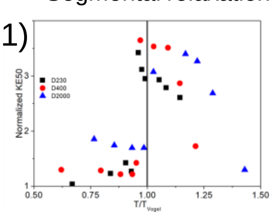
RESPONSIVE MATERIALS APPROACH

1) Temperature / Segmental relaxations

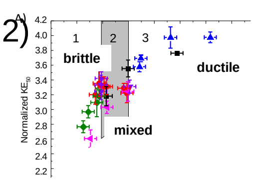
2) Molecular weight between crosslinks (Mc)

3) Non-covalent interactions (polarity)

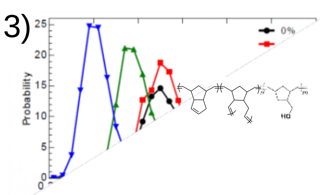
1)



2)



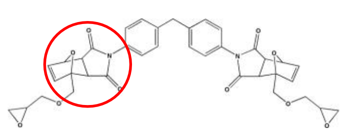
3)



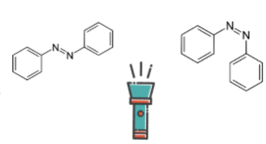
If we can change temperature, Mc, or polarity dynamically then we can make dynamically responsive polymer network glasses

Questions

- How many responsive groups?
- How should we organize them?
- How fast is local response?
- How does local response perturb surrounding polymer and how fast?
- How does the response depend on the polymer and environment?



Diels-Alder
(thermal Mc change)



Azobenzene
(optical shape change)

ACKNOWLEDGEMENTS

Resins and Adhesives:

ARL: Joseph Dennis, Tim Sirk, Randy Mrozek, Ngon Tran, Alice Savage, Kevin Masser, Dan Knorr

University of Chicago: Juan de Pablo, Stuart Rowan, Heinrich Jaeger

Northwestern University: Ken Shull

Polymer Processing:

ARL: Randy Mrozek, Dayne Plemmons, Brian Morgan, Chris Gold, Gene Napadensky, Rick Beyer

Case Western Reserve University: Gary Wnek, Eric Baer, Eric Davis

New Jersey Innovation Institute: Mike Jaffe

Peak Nano, LLC: Mike Ponting

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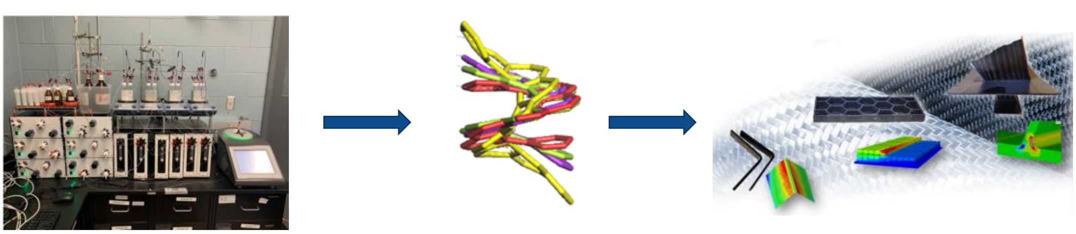
Materials Discovery and Development of Aerospace Composites



Dr. Davide Simone
Air Force Research Laboratory
RXCCM
6/15/22

USSF

AFRL
THE AIR FORCE RESEARCH LABORATORY

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AFRL at a Glance

Employees
1,100 Military (USAF/USSF)
5,400 Civilians
4,700 Contracted Personnel

3 in 5 Gov. Civilians are Scientists and Engineers (S&E)

79% of CIV S&Es hold an MS or Higher
33% Hold a PhD

OHIO
**HUMAN PERFORMANCE | *AEROSPACE SYSTEMS | HEADQUARTERS | MATERIALS & MANUFACTURING | SENSORS

USAF School of Aerospace Medicine
- Human Systems Integration
- Airman Systems

NEVADA
AFWERX
- Las Vegas, NV
- Austin, TX
- Washington D.C.

CALIFORNIA
*AEROSPACE SYSTEMS WEST

HAWAII
DIRECTED ENERGY
- Maui Research Site

NEW MEXICO
SPACE VEHICLES
DIRECTED ENERGY

TEXAS
AIRMAN SYSTEMS
**HUMAN PERFORMANCE
- Ft. Sam Houston

NEW YORK
INFORMATION

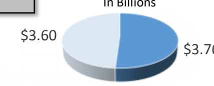
VIRGINIA
AF OFFICE OF SCIENTIFIC RESEARCH
- London, UK
- Tokyo, Japan
- Santiago, Chile

TENNESSEE
*AEROSPACE SYSTEMS

FLORIDA
MUNITIONS

$7B+ Funding (FY20)

AFRL Budget
In Billions



- AFRL Budget Authority
- External Customer Funds

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Materials & Manufacturing Directorate

465 $M Total Resources (FY19, 2.2xCore)
400 ksqft, 9 Bldgs (55% Labs)

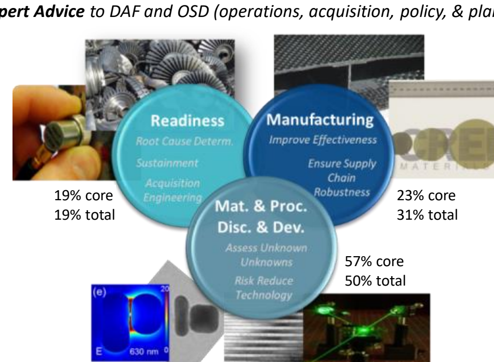
400 Gov. Staff (373 civ/27 mil, 50% PhD)
350 FTE On-site Staff, 50% PhD

Accelerating Technologies, Industrial Base, & Capabilities

Impose (Avoid) Tech Surprise *via Leading Cutting-Edge Foundational Research*

Risk-Abate with Industry *to Insure Supply (materials, components, processes)*

Expert Advice *to DAF and OSD (operations, acquisition, policy, & planning)*



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Cost-Imposing Technological Superiority Begins with Materials & Processes

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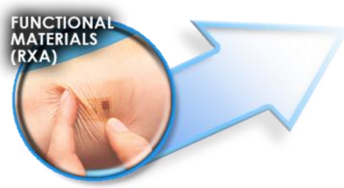
Core Technical Competencies

Technology Applications for our Airmen

- CERAMIC MATRIX COMPOSITES
- POLYMER MATRIX COMPOSITES
- METALS
- MATERIALS STATE AWARENESS



- MATERIALS FOR SURVIVABILITY AND PROTECTION
- MATERIALS FOR ISR AND ELECTRONIC WARFARE
- MATERIALS FOR MAN-MACHINE INTERFACE

Aerostructures
Agile Manufacturing
Airmen Performance Assessment
Energy Efficiency and Assurance
Hypersonics
Integrated Computational Materials Science and Engineering (ICMSE)
Intelligence, Surveillance, and Reconnaissance (ISR)
M&P Specification Standards
Mishap Prevention
Munitions
Nuclear Deterrence
Propulsion
Quick Reaction S&T Support
Space
Specialty Materials Affordability
Survivability
Sustainment

- SYSTEMS SUPPORT

- MANUFACTURING FOR ELECTRONICS AND SENSORS
- MANUFACTURING FOR PROPULSION AND STRUCTURES

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RX Research Teams

PMC Materials & Processing (RXCCM)
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- *Composite Processing Science*
- *Multifunctional Composite Structures*

Ceramics Materials & Processing (RXCCM)
Dr. Mike Cinibulk michael.cinibulk@us.af.mil
- *Fiber Reinforced Composites*
- *Environmental Effects*

Composites Performance (RXCCP)
Dr. Craig Przybyla craig.przybyla@us.af.mil
- *Continuous Fiber Reinforced Composite Behavior & Life Prediction*
- *Ceramic Matrix Composite Durability in Extreme Environments*

Metals Materials & Processing (RXCM)
Dr. Eric Payton eric.payton@us.af.mil
- Metals Additive Manufacturing and Processing Science
- Discovery and Design of New Alloys for Extreme Environments

Metals Probabilistic Performance Prediction (RXCM)
Dr. Todd (TJ) Turner todd.turner.5@us.af.mil
- High temperature durability assessment
- Location-specific (microstruct.-sensitive) probabilistic property prediction

Characterization Sensing and Analytics (RXCA)
Dr. Mike Uchic michael.uchic@us.af.mil
- *Materials characterization, with focus on nondestructive methods*
- *Analytics & uncertainty quantification*

Digital Manufacturing (RXMS)
Dr. Sean Donegan sean.donegan@us.af.mil
- Material Process Monitoring & Automation
- Data Analytics & Visualization for Manufacturing

Biological Materials & Processing (RXAS)
Dr. Nancy Kelley-Loughnane nancy.kelley-loughnane.1@us.af.mil
- Biomacromolecular-Material Interactions
- Synthetic Biology for Materials

Polymers and Responsive Materials and Processing (RXAS)
Dr. Christopher Crouse *christopher.crouse.1@us.af.mil*
- Conformal & compliant materials
- Novel responsive devices and architectures

Integrated Opto-Electronic Materials & Processing (RXAN)
Dr. Robert Bedford robert.bedford@us.af.mil
- Infrared Detectors & Quantum Sources
- Integrated Photonics

Agile Electronic Materials & Processing (RXAN)
Dr. Mike McConney *michael.mcconney.1@us.af.mil*
- High Power & Frequency Electronic Materials
- Reconfigurable RF Materials

Structured Optical Materials & Processing (RXAP)
Dr. Jonathan Vernon jonathan.vernon.2@us.af.mil
- Responsive Optical Material Systems
- Optical Thin Films and Coatings

Non-Linear EM Materials & Processing (RXAP)
Dr. Joy Haley joy.haley.1@us.af.mil
- Source Materials
- Broadband Nonlinear Materials

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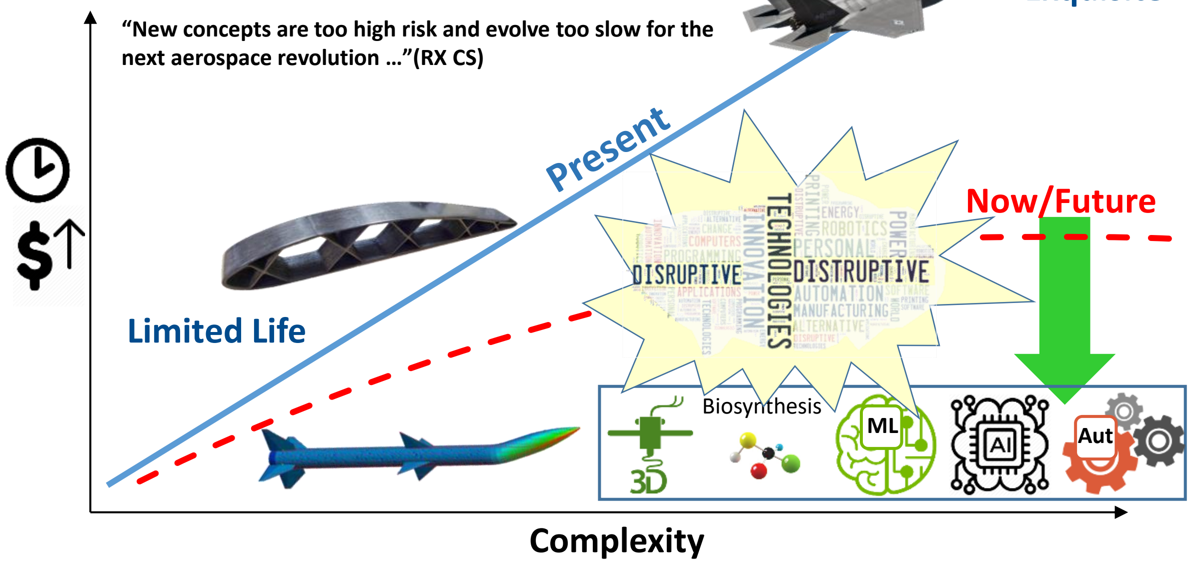
Enabling Capabilities Faster



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Graduate and Post-Doc

AFRL

Materials and Manufacturing Directorate
Graduate and Postgraduate Programs

Graduate Programs

SOCHE Intern	SOCHE strives to find internships for students at all academic levels including high school, undergraduate, graduate, and post-doctorate. DEADLINE: Open	
AFRL SCHOLARS PROGRAM	The AFRL STEM Workforce Development Program Portfolio is administered by Universities Space Research Association (USRA). USRA's team is dedicated to ensuring quality programs are offered at all supported sites and that scholars and mentors have a fulfilling, worthwhile experience that promotes interest and career development in science, technology, engineering, and mathematics. DEADLINE: JAN 10th	
AFRL MINORITY LEADERS - RESEARCH COLLABORATION PROGRAM	The objective of AFRL ML-RCP is to enable, enhance, and expand the research capabilities of Historically Black Colleges and Universities (HBCU) and Minority Serving Institutions (MSI) through collaborative research efforts with AFRL. The program has been recognized as a model for diversity engagements, enabling more than 750 students and 200 faculty participants from 40 partnering institutions to collaborate on AFRL directed research projects. DEADLINE: Open	
NATIONAL SECURITY INNOVATION NETWORK	The **X-Force Fellowship** is a summer internship program that provides graduate students and recent graduates a chance to serve their country by solving real-world national security problems in collaboration with the U.S. military. DEADLINE: DEC 17th	
SMART SCIENCE, MATHEMATICS, AND RESEARCH FOR TRANSFORMATION PART OF THE NATIONAL DEFENSE EDUCATION PROGRAM	The SMART Scholarship-for-Service Program is a combined educational and workforce development opportunity for undergraduate, master's, and doctoral STEM students. SMART Scholars receive full tuition, annual stipends, and employment with the DoD after graduation. DEADLINE: DEC 1st	
AFRL STEM Student Employment Program (SSEP)	The STEM Student Employment Program provides internship opportunities for undergraduate and graduate students in STEM fields with DoD Science and Technology Reinvention Laboratories (STRLs). DEADLINE: Open	
AFRL Summer Faculty Fellowship Program	The U.S. Air Force Research Lab Summer Faculty Fellowship Program offers hands-on exposure to Air Force research challenges through 8- to 12-week research residencies at participating Air Force research facilities for full-time science, mathematics, and engineering faculty and/or students at U.S. colleges and universities. DEADLINE: DEC 13th	
DAGSI Defense Associated Graduate Student Innovators	DAGSI's mission is to develop and support world-class graduate engineering education and research programs, thereby contributing to Ohio's economic growth and development. The DAGSI partnership effectively expands regional engineering education and research opportunities at the master's and doctoral levels. DEADLINE: FEB 7th	
Direct Hire Authority (DoD DHA)	The Direct Hire Authority for the DoD for Post-Secondary Students and Recent Graduates allows for internships for qualified post-secondary students and recent graduates in non-STEM fields within AFRL/RX. DEADLINE: Open	

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AFRL-2022-2309

Materials and Manufacturing Directorate
Graduate and Postgraduate Programs

Graduate Programs (Continued)

National Defense Science and Engineering Graduate Fellowship Program	The DoD National Defense Science and Engineering Graduate (NDSEG) Fellowship Program is a competitive fellowship that is awarded to U.S. citizens, U.S. nationals, and U.S. dual citizens who intend to pursue a Doctoral degree aligned to the DoD services Broad Agency Announcements (BAAs) in research and development at a U.S. institution of their choice. DEADLINE: FEB 7th	
NSF National Science Foundation	The mission of NSF's **Summer Scholars Internship Program (SSIP)** is to develop undergraduate and graduate student potential through exposure to relevant science and engineering policy, research and education issues and programs; and to encourage students to earn graduate degrees and pursue careers in science, technology, engineering, and mathematics (STEM) fields. DEADLINE: APR 15th	

Graduate and Postgraduate Programs

PATHWAYS	The Pathways Program offers federal internship and employment opportunities for current students, recent graduates and those with an advanced degree. There are three different paths available: Internship Program, Recent Grads Program & Presidential Management Fellows (PMF) Program. DEADLINE: Open	
Workforce Recruitment Program (WRP)	The Workforce Recruitment Program is a recruitment and referral program for college students and recent graduates with disabilities who are eager to demonstrate their abilities in the workplace through internships, temporary, or permanent employment in the Federal Government. DEADLINE: Applications open in late AUG	
NSF National Science Foundation	**Designing Materials to Revolutionize and Engineer our Future** Building a world-class materials science and engineering workforce proficient in the tools and techniques necessary to accelerate the discovery, development, and deployment of advanced materials. DEADLINE: APR 15th	
Palace Aquire	The Palace Acquire (PAQ) program is an Air Force program to recruit, train and develop college graduates to become professional Air Force Civilian Scientists and Engineers. PAQ provides training and development, mentoring, and real world work experience leading to professional employment. DEADLINE: Open	

Postgraduate Programs

NATIONAL SECURITY INNOVATION NETWORK	The **Technology and National Security Fellowship** is an opportunity for technologists and entrepreneurs to serve their country by embedding with key decision-makers at the top levels of the U.S. Government. DEADLINE: JUN 30th	
AF Science & Technology Fellowship Program	The Air Force Science & Technology Fellowship Program offers nationally competitive fellowship awards to postdoctoral and senior scientists to perform collaborative research at U.S. Air Force research facilities across the country. DEADLINE: Varies	

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AFRL-2022-2309

THE AIR FORCE RESEARCH LABORATORY

USSF

Undergraduate

AFRL

Materials and Manufacturing Directorate Undergraduate Student Programs

PATHWAYS for Students & Recent Graduates to Federal Careers
The Pathways Program offers federal internship and employment opportunities for current students, recent graduates and those with an advanced degree. There are three different paths available: Internship Program, Recent Grads Program & Presidential Management Fellows (PMF) Program. DEADLINE: Varies

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The AFRL STEM Workforce Development Program Portfolio is administered by Universities Space Research Association (USRA). USRA's team is dedicated to ensuring quality programs are offered at all supported sites and that scholars and mentors have a fulfilling, worthwhile experience that promotes interest and career development in science, technology, engineering, and mathematics. DEADLINE: JAN 10th

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LEGACY
LEGACY Apprentice. The final phase of the LEGACY program sharpens the students' ability to multi-task and complete the research process. The students' polished professional skills will complement the objective, which is a smooth transition to the workforce. DEADLINE: MAR

Premier College Intern Program
The Premier College Intern Program is designed to prepare participants for future mission critical and specialty positions in the Air Force through 10-12 week paid summer internships. Interns will complete special projects using cutting edge technology, while under the mentorship of senior managers. DEADLINE: DEC

National Security Innovation Network
The **X-Force Fellowship** is a summer internship program that provides undergraduates a chance to serve their country by solving real-world national security problems in collaboration with the U.S. military. DEADLINE: DEC 17th

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AFRL-2022-2309

Materials and Manufacturing Directorate Undergraduate Student Programs

SMART Science, Mathematics, and Research for Transformation – Part of the National Defense Education Program
The SMART Scholarship-for-Service Program is a combined educational and workforce development opportunity for undergraduate, master's, and doctoral STEM students. SMART Scholars receive full tuition, annual stipends, and employment with the DoD after graduation. DEADLINE: DEC 1st

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Direct Hire Authority (DoD DHA)
The Direct Hire Authority for the DoD for Post-Secondary Students and Recent Graduates allows for internships for qualified post-secondary students and recent graduates in Non-STEM fields within AFRL/RX. DEADLINE: Open

United States Air Force Academy
The Cadet Summer Research Program (CSRP) provides opportunities for cadets to solve relevant problems, learn through real-world application of classroom principles, and build lasting collaborative relationships while participating in research at the various military, government, and civilian facilities throughout the world. DEADLINE: SEP - OCT

Center for Excellence in Education
The DoD Summer Lab Research Intern Program pairs college students with DoD lab internships, using a blend of virtual and in-person modalities to nurture careers of excellence and leadership in STEM for academically talented students. DEADLINE: JAN 14th

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Student STEM programs (K-12)

AFRL

Materials and Manufacturing Directorate Student STEM Programs (K-12)

Internship Opportunities

PATHWAYS for Students & Recent Graduates to Federal Careers
The Pathways Program offers federal internship and employment opportunities for current students, recent graduates and those with an advanced degree. There are three different paths available: Internship Program, Recent Grads Program & Presidential Management Fellows (PMF) Program. DEADLINE: Varies

SOCHE Intern
SOCHE strives to find internships for students at all academic levels including high school, undergraduate, graduate, and post-doctorate. DEADLINE: Open

LEGACY
LEGACY Jr. Apprentice introduces students to real-world research by providing quality mentors in world-class facilities. Students will learn professional skills while building their understanding of current research and how it is conducted. The student will have multiple mentors to help prepare them for college and the next phase of the LEGACY program. DEADLINE: NOV-DEC

Wright Scholar Research Assistant Program
The Wright Scholar Research Assistant program is an Air Force Research Laboratory initiative designed to expose high school juniors and seniors to various disciplines of engineering and science in an effort to further their interest in future STEM career options. DEADLINE: JAN 10th

AFRL Scholars Program
The AFRL STEM Workforce Development Program Portfolio is administered by Universities Space Research Association (USRA). USRA's team is dedicated to ensuring quality programs are offered at all supported sites and that scholars and mentors have a fulfilling, worthwhile experience that promotes interest and career development in science, technology, engineering, and mathematics. DEADLINE: JAN 10th

Center for Excellence in Education
Research Science Institute (RSI) Massachusetts Institute of Technology (MIT) Internship: RSI is the first cost-free to students, summer science & engineering program to combine on-campus course work in scientific theory with off-campus work in science and technology research. Completion of the RSI MIT Internship is required for consideration for an undergraduate on-site Internship within a Department of Defense (DoD) installation to understand the breadth and depth of DoD research for future career planning. DEADLINE: JAN 10th

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AFRL-2022-2309

Materials and Manufacturing Directorate Student STEM Programs (K-12)

Team Competitions & Educational Outreach

FIRST LEGO League
FIRST™ LEGO® League Explore presents a new and exciting Challenge each year to ignite the creativity of children age 6 to 14. While exploring the real-world theme, teams use basic engineering concepts to build a model made of LEGO® elements. DEADLINE: MAY
EXPLORE – Ages 6-10 | CHALLENGE – Ages 9-14

FIRST Tech Challenge
FIRST Tech Challenge is a robotics sport-like competition for students grades 7-12. Teams of up to 15 students design, build, and program robots to compete head-to-head against other teams. Teams develop strategies and build their robots based on comprehensive engineering principles. DEADLINE: TBD

FIRST Robotics Competition
Under strict rules and limited time and resources, teams of high school students are challenged to build industrial-size robots to play a difficult field game in alliance with other teams, while also fundraising to meet their goals, designing a team "brand," and advancing respect and appreciation for STEM within the local community. DEADLINE: Varies

Wizards of Wright
Resources for teachers, parents, and students. Ranges from arranging WPAFB experts to visit classrooms to give STEM lessons, borrowing kits for lessons, STEM activities for home, to resources for homeschooling families. DEADLINE: Open

SEMEDS
SEMEDS is a unique program that brings local students and their teachers to Wright-Patterson Air Force Base (WPAFB) to operate state-of-the-art scanning electron microscopes in a real life laboratory setting. DEADLINE: Open

LEGACY
LEGACY Craftsman is a free, STEM-inspired, hands-on camp for 11-15 year old students. This camp will build knowledge while reinforcing self-confidence and leadership. DEADLINE: MAR 1st

WPAFB Educational Outreach Tutors
Teachers or other school personnel can request volunteers to come to their school during school hours to tutor students. There are many wonderful, dedicated volunteers wanting to assist in nearly every subject taught. DEADLINE: Open

And Much More!
DEADLINE: Various
Science Fair · Air Force Science & Engineering Fair · Read Across America · Jobshadowday Program · STARBASE Wright-Patt · Mentors

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ACS Chemistry for Life®

ACS Webinars CLICK • WATCH • LEARN • DISCUSS

Audience Survey Question

ANSWER THE QUESTION ON THE INTERACTIVE SCREEN IN ONE MOMENT

Which Armed Service was to first to test air vehicles and in which year did they do so?

- US Air Force, 1947
- US Army Air Service, 1918
- US Army Signal Corp, 1908
- US Army Air Corp, 1927

* If your answer differs greatly from the choices above **tell us in the chat!**

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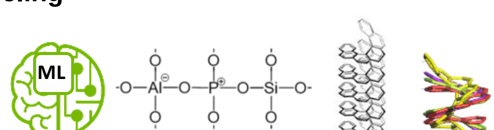
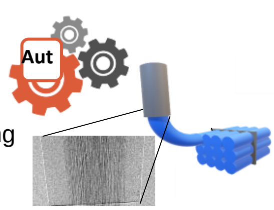
U.S. Air Force 75 Established 1947

PMC M&P addresses the design and synthesis of specialty polymers, real-time sensors, processing science, and predictive modeling

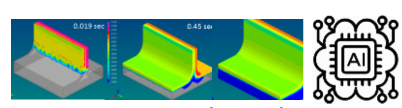
- **Materials Discovery**
  - Synthesis 600ºF - 1000ºF resins
  - Resin discovery via ML/AI
  - Geopolymers
  - SynBio
- **Agile Processing**
  - Additive Manufacturing and Infusion
  - Real-time measurements
  - Process modeling & Integrated sensing
- **Multifunctional**
  - Boron rich epoxies (Nuclear)
  - MXenes (CDEW)



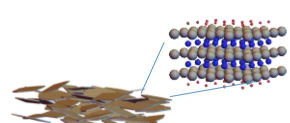
Domestic, low cost routes towards high performance, resins



Agile, low cost processes



Process automation and part unitization



Resilient structures

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INNOVATE, ACCELERATE, THRIVE – THE AIR FORCE AT 75

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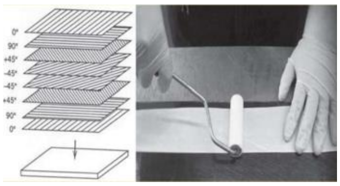
From Traditional to Agile Manufacturing

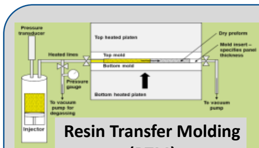
AFRL



Hand Lay-Up of PMC's

Autoclave Processing

⇓Time, ⇓Cost



Resin Transfer Molding (RTM)

Solvent-Free/Imidized Resin
Unitized Components
Tolerances
⇓Cycle Time
3D Preforms

3D Printed Composites

Rapid Prototyping
Complexity

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USSF

Key Metrics for Aerospace Resins

AFRL

Toughness- Resins tend to be highly crosslinked "oligomers".

Temperature Capability- Extending usage time and temperature would be advantageous to the physical limit of bond strengths.

Balance requisite viscosities/TOS for RTM and AM applications.

Water uptake- One of the main root causes of failure in PMC's. Dramatic loss in moisture during use initiates micro-cracks that lead to further ingress of moisture and oxygen.

No truly non-invasive in-situ monitoring tools during cure and post-cure.

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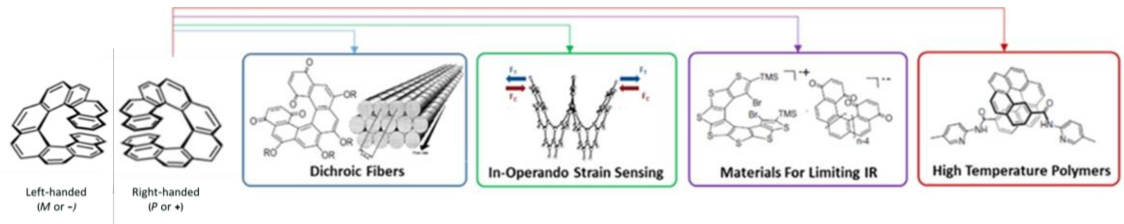
Air Force Interest With Helically Chiral Molecules and Polymers

AFRL



Hypothesis

- Thermally Robust monomers for high temperature applications.
- Large Dichroism along the helical axis, has implications for sensing.

Synthetic Hurdles

- Syntheses tend to be lengthy and low yielding.
- Enantioselective synthesis is key for some applications.

Highly dichroic, non-planar, oxidatively robust fused aromatic rings.

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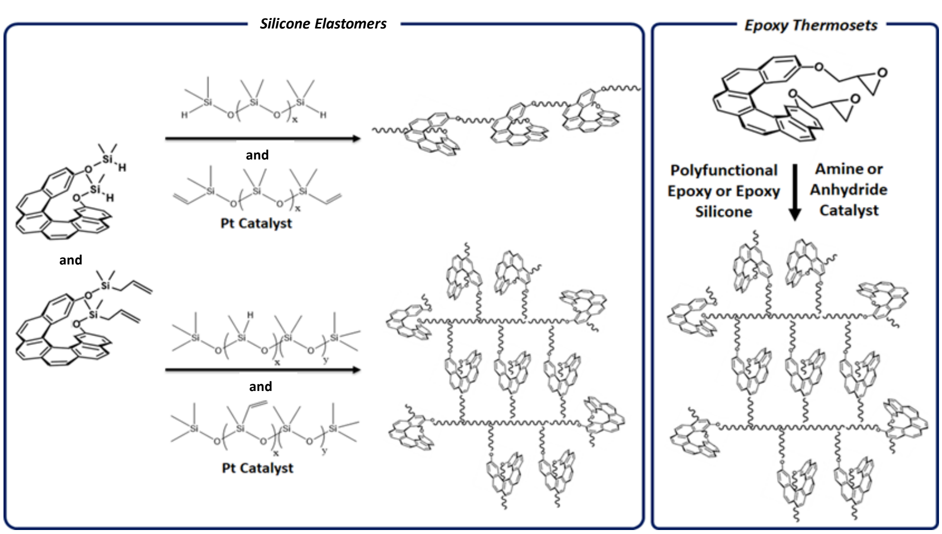
The Application: Strain Sensing

AFRL



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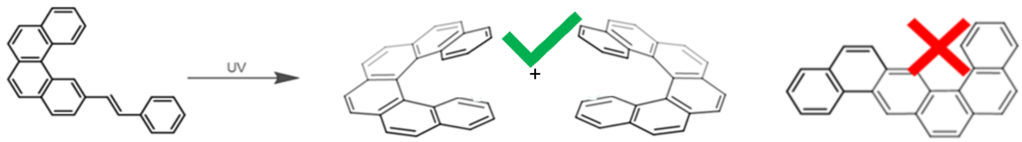
Optimization of Helicene Products



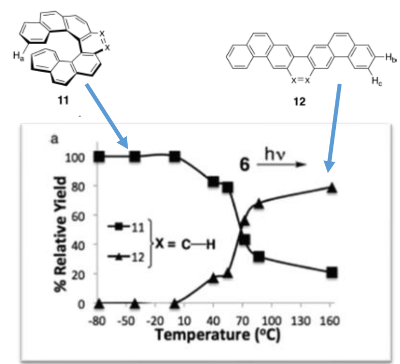
[4] + [1]

Precursor Design

Carbohelicene	Precursor*	% Yield
[6]	*[4]+[1]*	*87*
	[1]+[2]+[1]	60
	[2]+[1]+[1]	55
	[3]+[2]	25

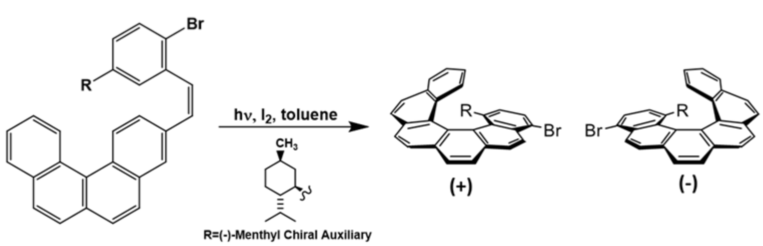
Carbohelicene	Precursor*	% Yield
[11]	*[4]+[1]+[4]*	*84*
	[4]+[3]+[2]	80
	[3]+[3]+[3]	54
	[6]+[4]	45

Thermodynamics vs Kinetics



Refs:
1. Laarhoven, W. H., Prinsen, W. J. C., (1984) Top. Curr. Chem. 1984, 125, 63–130.
2. Weber, J.; Clennan, E. L. The Journal of Organic Chemistry 2018, 84 (2), 817–830.

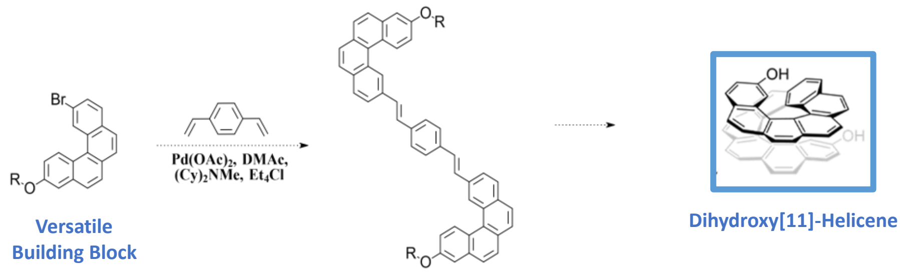
Inducing Enantioselectivity: Chiral Auxiliary Groups



Temperature (°C)	Ratio of Diastereomers (+/-)	Diastereomeric excess
+80	20:80	60%
+25	24:76	52%
0	38:62	24%
-78	98:2	96%

Refs:
1. Vanest, J.-M.; Martin, R. H Recueil des Travaux Chimiques des Pays-Bas 1979, 98 (3), 113–113.

Synthetic Futures: Multifunctional Helicene Precursors



DARPA-AMD Program Definition

Increase the Pace of Discovery and Optimization
Develop **Closed Loop Systems** that Exploit, Build and Integrate Tools for:

1) Extracting Existing Data from Databases and Text;

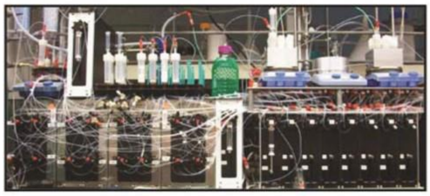
2) Execute Autonomous Experimental Measurement and Optimization;

3) Incorporate Computational Approaches to Develop Physics-Based Representations and Predictive Tools.

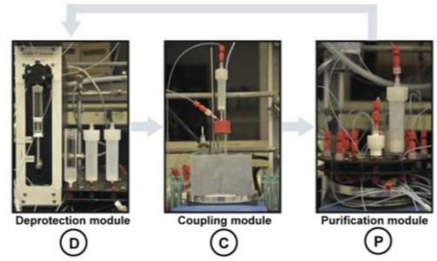
https://www.darpa.mil/program/accelerated-molecular-discovery

UIUC Molecule Maker Research: Modular Suzuki Couplings

Prof. Martin Burke, UIUC



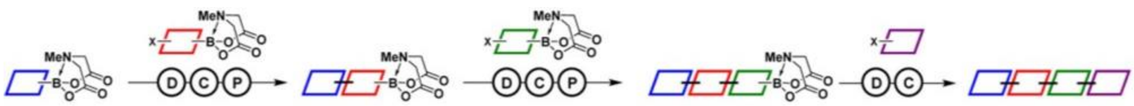
Molecule Maker



Suzuki Reaction: R-B(OH)$_2$ + R'-X $\xrightarrow[\text{Aqueous or Organic}]{\text{Pd, Base}}$ R-R'

Boronic Acid (or Ester)

R or R'=Aromatic, Alkene
X= -I, -Br, -OTf etc..



MIDA Borane

Modular Synthesis and Purification Using LC-MS as a DOR Probe

Science. 2015 March 13; 347(6227): 1221–1226.

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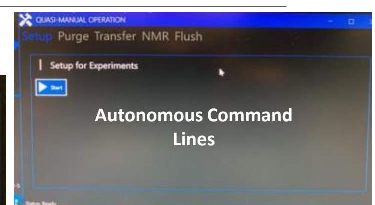
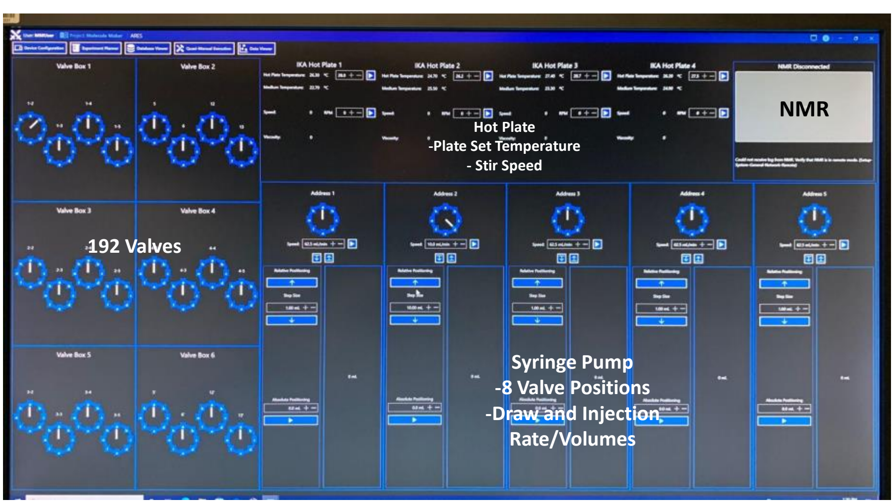
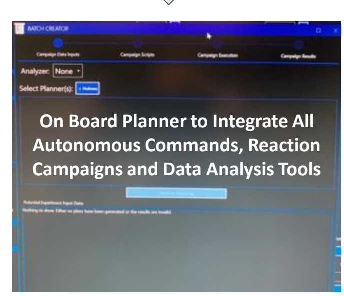
Molecule Maker ARES OS Dashboard







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AFRL's Version of the Molecule Maker

Reagents, Solvent, Waste

Inert Gas Bubblers

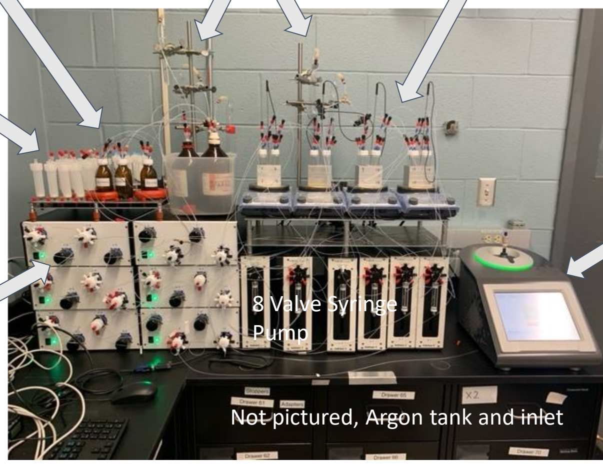
Hot Plate/Stirrer
16 vials x 20 mL

Workup and Silica Columns

Uv-vis
Spectrometer

Fluorescence
Detector

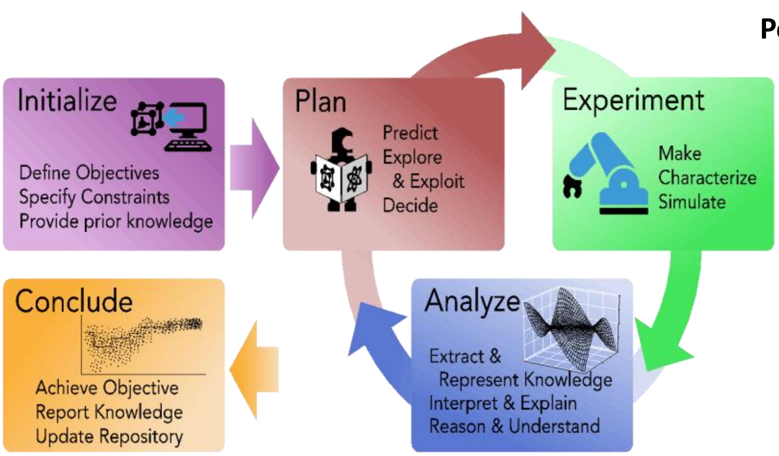
4/8 Teflon
Valve Array
(192 valves)



60 MHz(1.4T) ^{1}H and ^{19}F NMR
1D and 2D Capability

**First Molecule Maker with Closed Loop (Autonomous) NMR Analytical Tool:
Direct Structural Evidence of Reaction Outcome(s)**

Autonomous Research Process



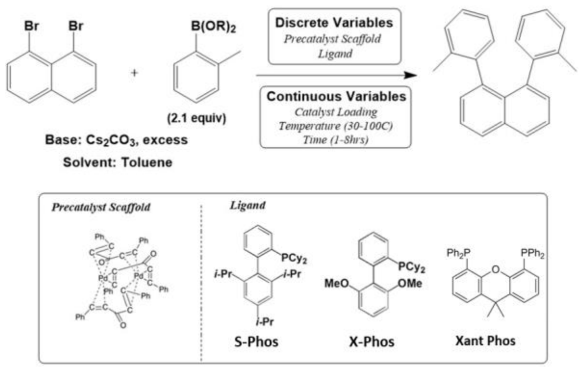
Experimental Convergence

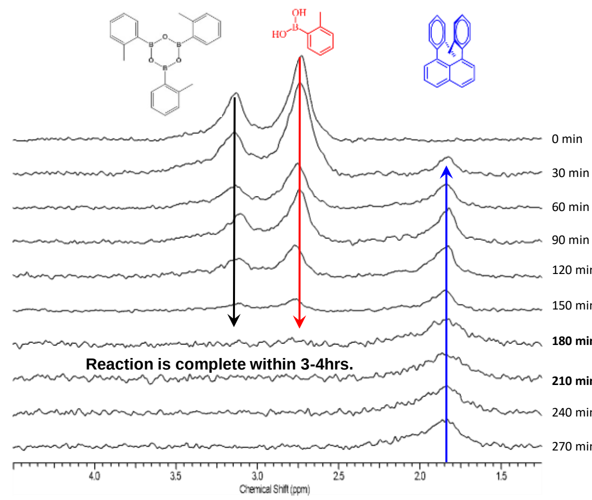
Power of Closed-Loop Iteration

- Autonomy: System designs its own experiments using AI & Machine Learning
- Automation: Execute experiments automatically Modeling: Integrate modeling & simulation directly in the loop
- Analysis Knowledge Representation
- Science through in-line hypothesis generation and testing
- More iterations >> More experiments

Stach et al. "Autonomous Experimentation Systems for Materials Development: A Community Perspective." Accepted for publication in Cell Press Matter, 2021.05

Semi-autonomous, closed loop NMR acquisition





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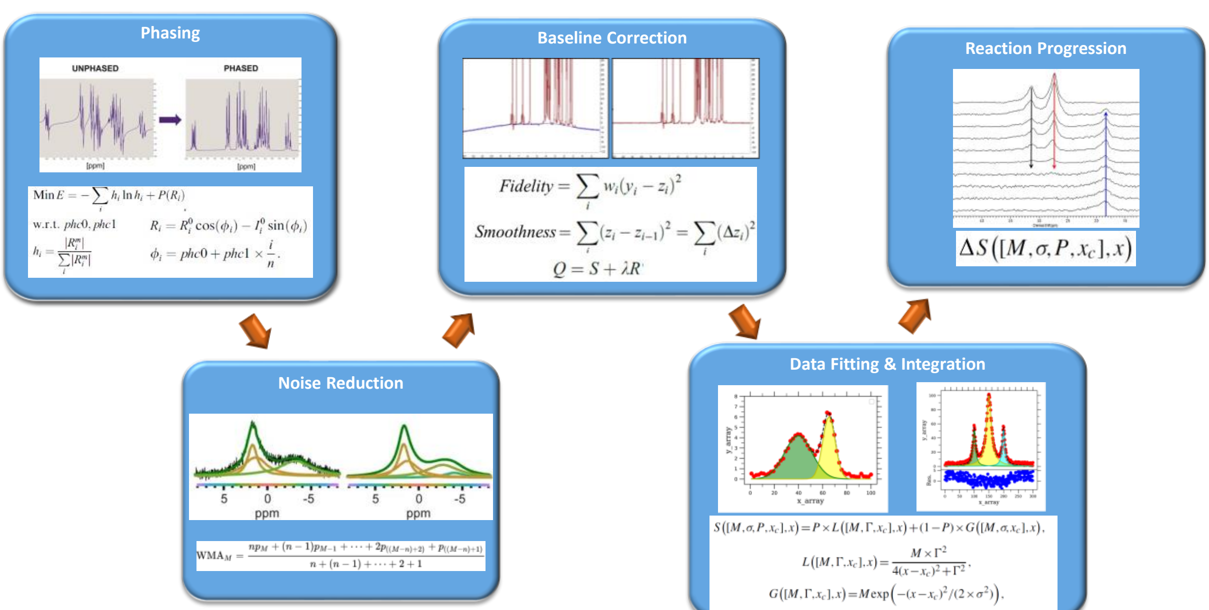
Autonomous NMR Data Workup and Analytics



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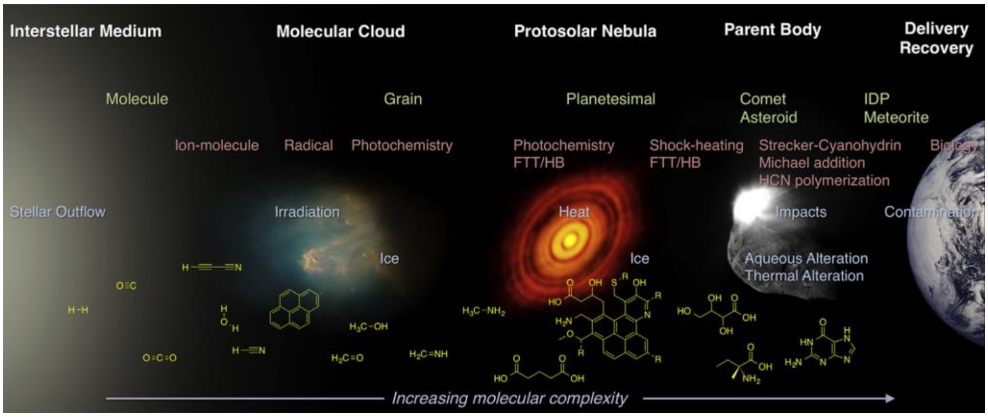
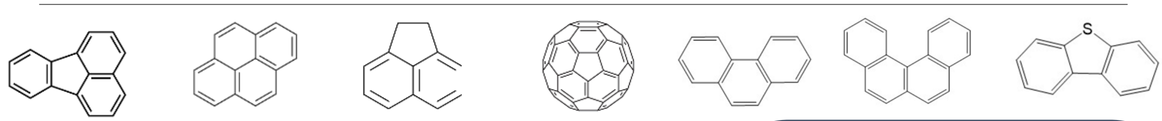
From Biotic to Extraterrestrial (Abiotic?) Organic Synthesis



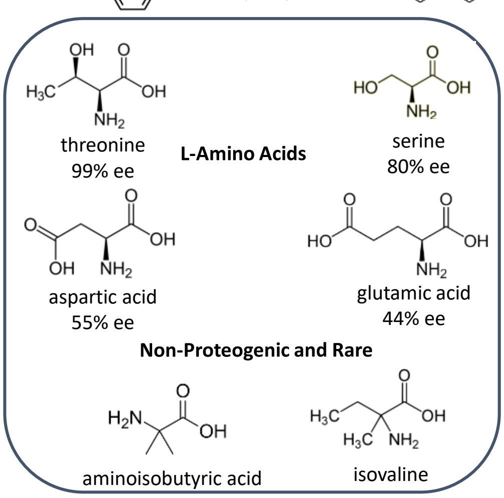
Glavin D. P., Alexander C. M. O'D., Aponte J. C., Dworkin J. P., Elsila J. E., and Yabuta, H. 2018. The origin and evolution of organic matter in carbonaceous chondrites and links to their parent bodies. In Primitive meteorites and asteroids, edited by Abreu N. Amsterdam, the Netherlands: Elsevier. pp. 205–271.

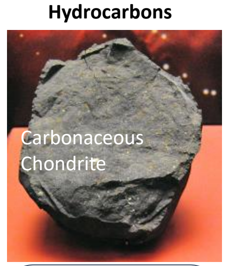
~10^9 kg/yr of organic carbon delivered to Earth

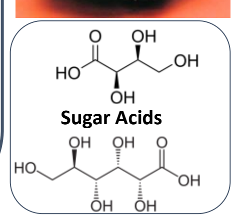
Extraterrestrial Sourcing of Organic Matter

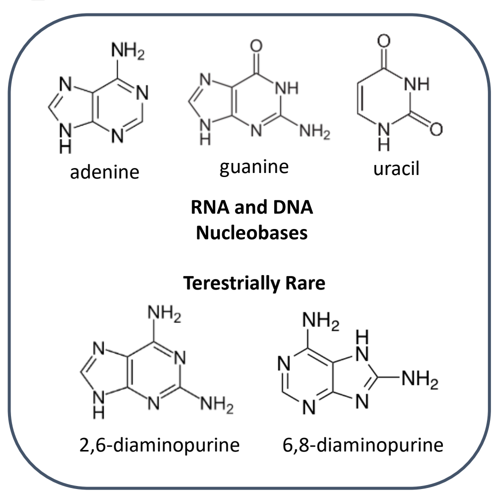


Aromatic Hydrocarbons









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