January 29, 2021

Dr. Thomas Epps, III (Director) | Dr. LaShanda Korley (Co-Director)

National Science Foundation
MRSEC
Materials Research Science and Engineering Centers
Award No. DMR-2011824

UD CHARM

CENTER FOR HYBRID, ACTIVE AND RESPONSIVE MATERIALS

Our Mission

Create a world-recognized hub of interdisciplinary integration and infrastructure development to **drive cross-cutting materials innovation**

Our Vision

Harness the integrated power of computational design, innovative synthetic and manufacturing processes, and nano-scale characterization to **unlock the substantial promise of complex, synthetic materials at multiple length/time-scales**

Outreach

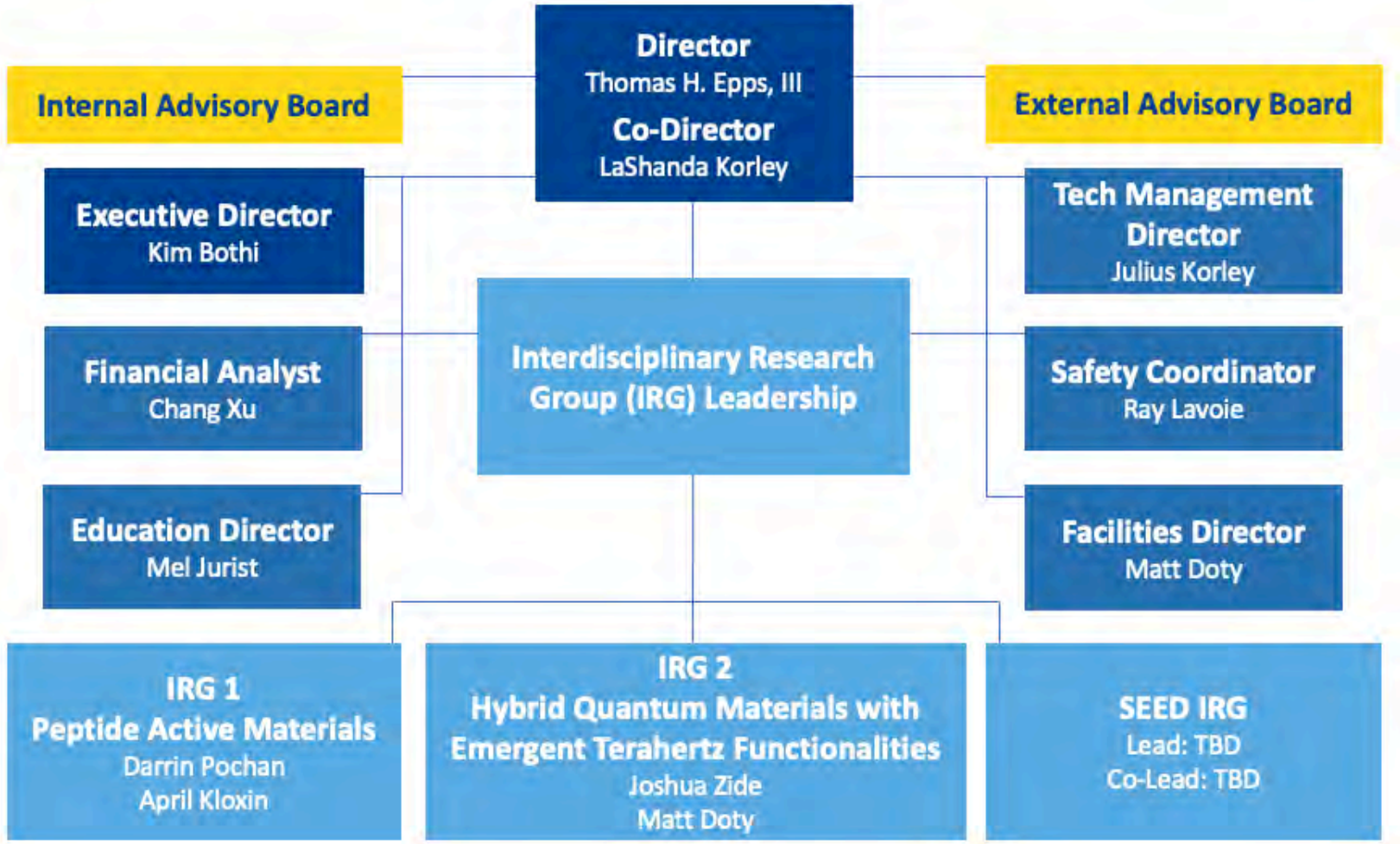
Leverage materials science as a platform to **enhance educational and diversity-focused programming to benefit under-resourced populations**

Thomas H. Epps, III
Director

LaShanda T. J. Korley
Co-Director

Kim Bothi
Executive Director

UD CHARM
Organizational Structure



Key Participants

Peptide Active Materials (PAMs)

Computationally designed peptides for targeted nanostructures, motion, and simple machines

IRG 1

Darrin Pochan: Co-Director

April Kloxin: Co-Director

Jeffery Saven (UPenn)

Paul Butler (NIST)

Eric Bloch

Thomas Epps, III

Joseph Fox

Eric Furst

Xinqiao Jia

Kristi Kiick

LaShanda Korley

Christopher Kloxin

Computational design – modeling **Molecule synthesis** **Molecule assembly** **Structure & properties**

Key Participants

Hybrid Quantum Materials with Emergent Terahertz Functionalities: (HQ-METs)

Understanding and controlling interfaces and transduction to create hybrid materials with emergent THz functionalities

IRG 2

Joshua Zide: Co-Director

Matthew Doty: Co-Director

Benjamin Jungfleisch

Lars Gundlach

Anderson Janotti

Stephanie Law

Branislav Nikolic

John Xiao

Garnett Bryant (NIST)

Growth **Theory/Design** **Characterization**

Core Team & Collaborators Continued

Julius Korley, PhD, MBA
Tech Management Director
UD Engineering

Mel Jurist
Education Director
UD Engineering K-12

Derrick Swinton, PhD
Dean for Natural Sciences
Claflin University

Sue Giancola, PhD
Sr. Associate Director
UD CRESP

Shelly Lasko
Administrative Assistant
UD Engineering

Cherese Winstead, PhD
Chair of Chemistry
Delaware State University

Shameeka Jelenewicz, MS
Education Researcher
UD CRESP

Chang Xu
Financial Analyst
UD Engineering

Tatiana Poladko, PhD
Founder and CEO
TeenSHARP

IRG 1

Peptide Active Materials (PAMs)

Motivation and Vision

IRG 1

Harnessing the immense polyaminoacid complexity of nature *without* billions of years of evolution

Nature-Inspired Materials

MOTIVATION:

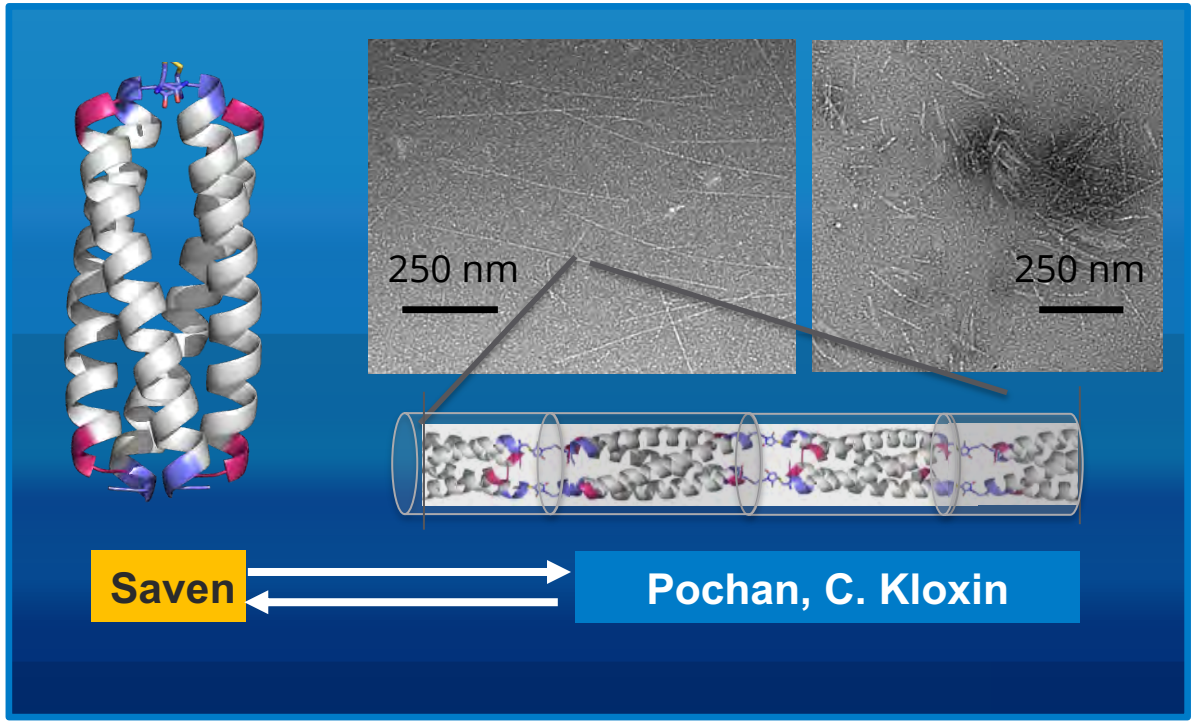
Life is possible due to **proteins**: polyaminoacid macromolecules with exquisite folded nanostructure producing specific function that is encoded in the amino acid sequence.

KEY CHALLENGE:

Restricted toolbox of natural or mutated protein structures limits design of non-natural materials.

VISION:

Computational design to realize **synthetic peptides** that fold and assemble into **rigid, protein-like building blocks** to produce designed **Nanostructure** (Aim 1), **Motion** (Aim 2), and **Simple Machines** (Aim 3).



Saven, C. Kloxin, Pochan, and coworkers, "Polymers with controlled assembly and rigidity made with click-functional peptide bundles," *Nature* **574** (2019): 658-662

Approach

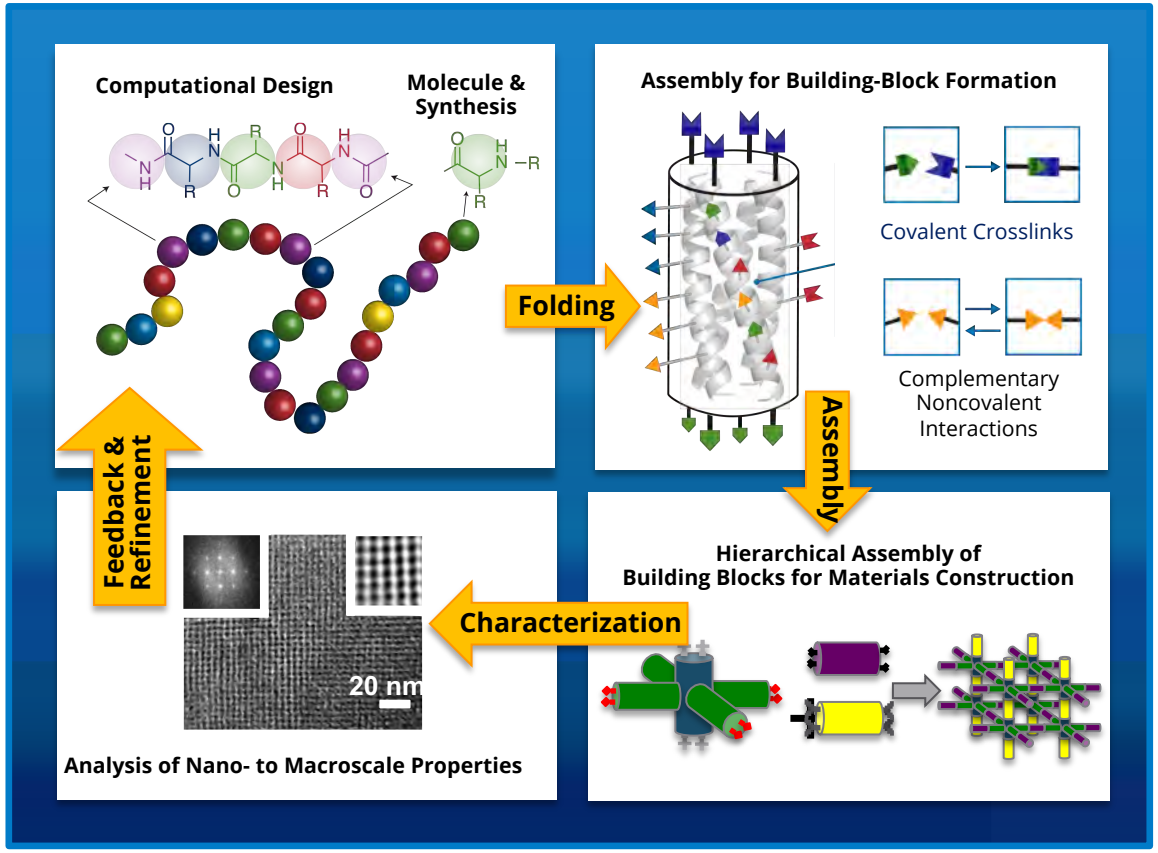
IRG 1

Biomolecules for Non-Biological Things

- **Computational design** to direct building block synthesis
- **Incorporate *any* natural or non-natural amino acid to promote desired assembly for building-block formation,** enabled by innovative synthetic tools and protein expression
- **Control hierarchical assembly and mitigate defects** through kinetic pathway of assembly and building-block design
- **Nanoscale characterization** to **verify** structure and **refine** computational design

Objectives and Goals Years 1 & 2

1) Understand and control formation of different building blocks and their **connectivity** to **create 1D & 2D nanomaterials**
2) Understand and control **(bio)polymer design and conjugation to 1D & 2D nanomaterials** for actuating **motion**
3) Establish **key experimental subunits for construction of simple machines** guided by theory



IRG 2

Hybrid Quantum Materials with Emergent Terahertz Functionalities (HQ-METs)

Motivation and Impact

IRG 2

Emergent THz functionality through controlled interactions between THz excitations

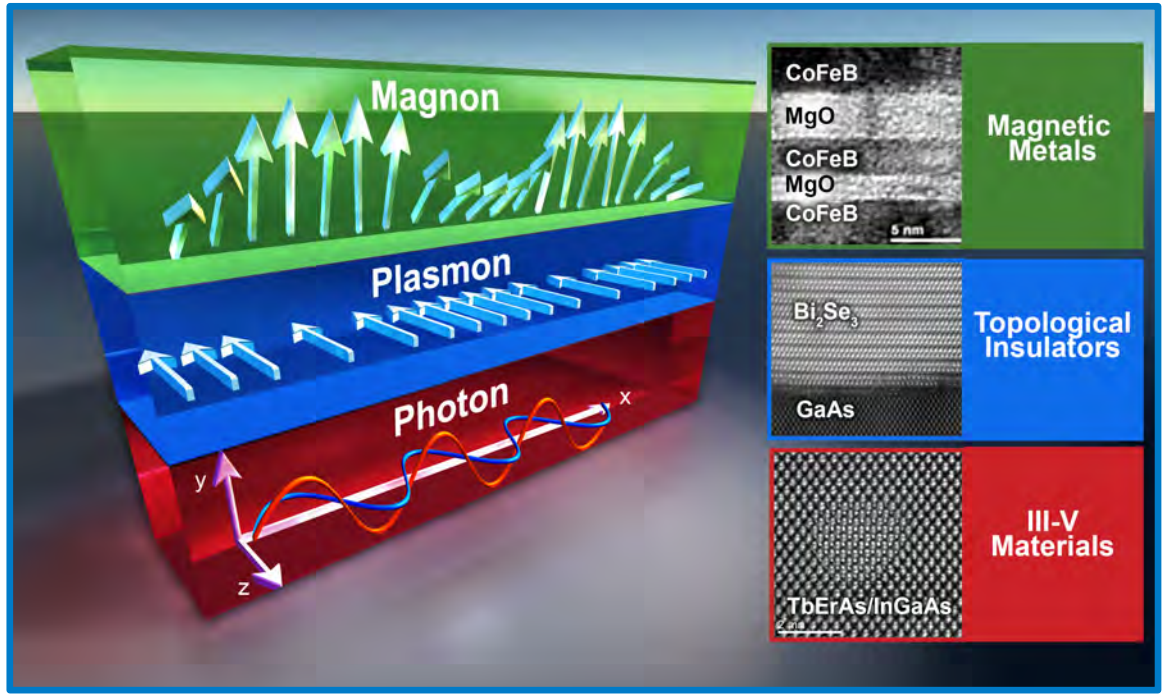
MOTIVATION: Opportunities for the **terahertz** are limited by technologies that lag other wavelength ranges (i.e., RF and photonic technologies).

KEY CHALLENGE: Material platforms tend to be **well-suited for one** THz functionality (e.g., sources, waveguides, detectors) and **poorly suited for others**.

VISION: Understanding and controlling materials integration to **create hybrid materials** that allow **transduction** of excitations across the interfaces, **control** of emergent THz functionality, and **creation** of hybridized states with fundamentally new properties.

CONSTITUENTS:

1) Magnetic Heterostructures (magnons, high-power THz sources through spin-to-charge conversion)
2) Topological Insulators (spin-momentum locked plasmons)
3) Novel III-Vs (THz photon generation / detection)



THz excitations in each of the three material constituent families of our hybrid materials. Insets show TEM images of examples of materials from each family grown at UD.

Aims and Expected Accomplishments

IRG 2

Fundamental understanding of hybrid materials and transduction

Understanding enables technology

AIM 1

Establish, understand, and enhance transduction (weak coupling) in our new hybrid materials by understanding and controlling the material constituents and their interfaces.

OUTCOME 1

Fundamental understanding of hybrid interfaces and their impact on the strength of transduction.

AIM 2

Understand, combine, and control emergent THz functionalities in our hybrid materials.

OUTCOME 2

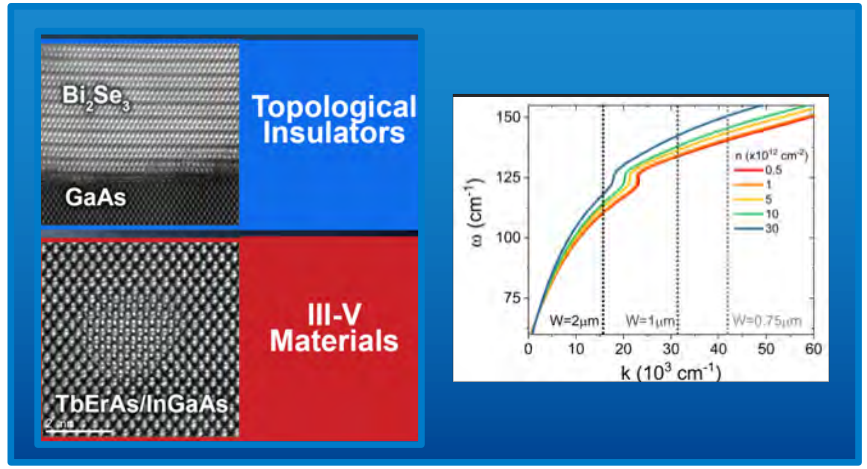
Understanding of:
1) the dynamics of interactions between THz excitations in material constituents, and
2) the physics of in situ modulation of the strength or nature of transduction.

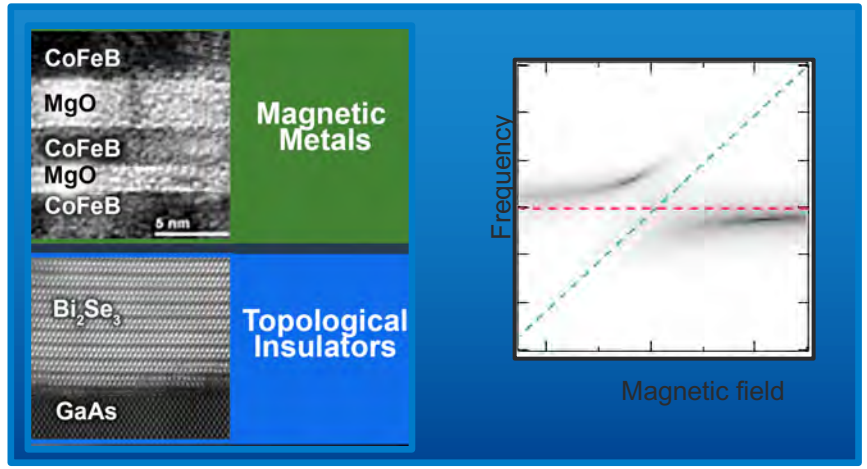
AIM 3

Approach the strong-coupling regime, creating hybridized states consisting of at least two excitations in distinct materials constituents.

OUTCOME 3

Fundamental understanding of the nature and emergence of hybrid excitations as a function of material composition and structure.



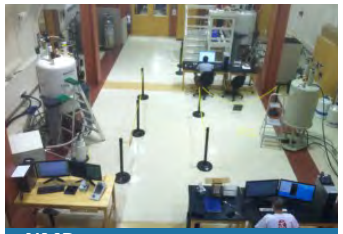


Space and Facilities

A community of materials research resources across campus

Advanced Materials Characterization Lab (AMCL)

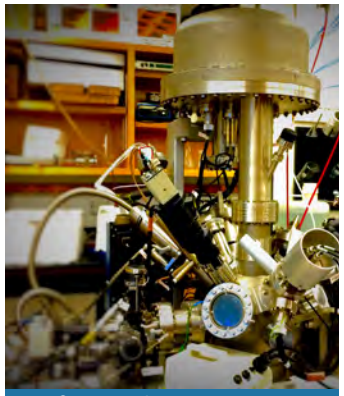
UD Nanofabrication Facility (UDNF)



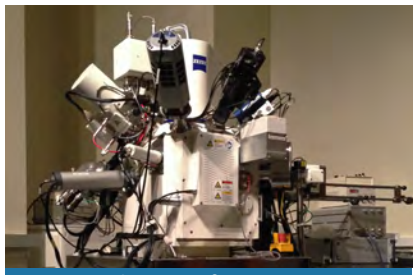
NMR Laboratory

DBI Bioimaging

Materials Growth Facility



Surface Analysis Laboratory



W.M. Keck Center for Advanced Microscopy (CAMM)

K-12 Outreach & Community Engagement

High Throughput Experimentation Facility

UD Science, Technology & Advanced Research (STAR) Campus will be new home to MRSEC UD3C & 6 co-PIs

Advanced synthesis & characterization labs (UPLC, HPLC, MS, NMR, CD)

Shared co-PI collaborative research labs

Education and Outreach Highlights
Soft Matter for All

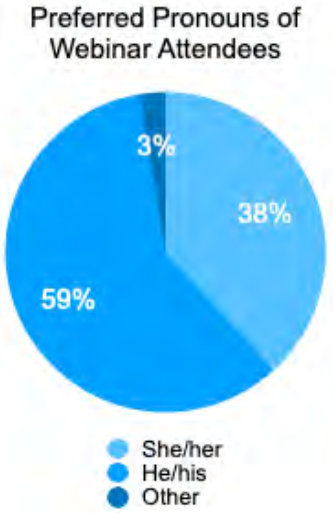
- Partnership between Princeton & UD MRSECs
- 18 grad student & postdoc presenters from 13 institutions
- Keynotes by Prof. Paula Hammond/MIT and Prof. Joe DeSimone/Stanford

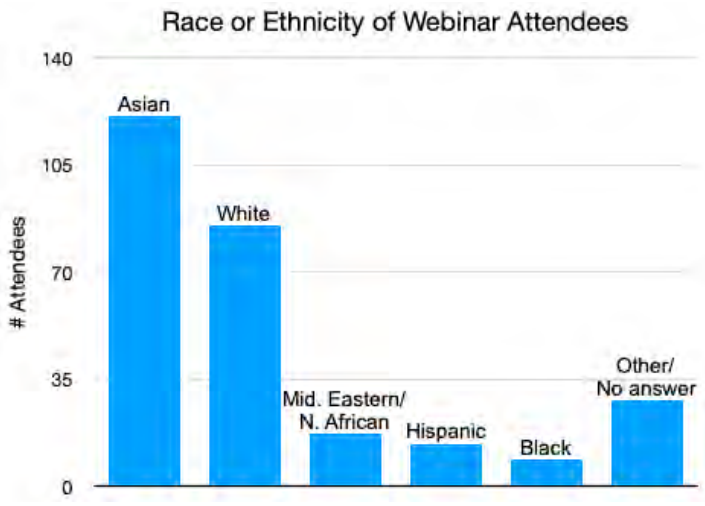
274 Unique webinar viewers

Registrants from **64+** institutions

Representing **10+** countries

1.1K Twitter Live viewers





Education and Outreach Highlights
TeenSHARP High school student research experience (HighRise)

Sustained and diverse research experience for minority high school students

- New 6-year longitudinal program
- ***Leverages TeenSHARP's college preparatory infrastructure for Black and Latinx students***
- ***8-week research internship program modeled after UD's ACS Project SEED site***
- Engage 2 cohorts of students for 3 years (sophomore to senior)
- Co-mentored by **trained** faculty, graduate student, and undergrad student teams

Short-term Outcomes

- ***Enhanced preparation for undergraduate experience***
- ***Increased confidence in pursuit of undergraduate education***
- Increased familiarity with 'unwritten rules'
- Increased number of URGs who effectively pursue undergraduate STEM education

Education and Outreach Highlights
DESU/CU MRSEC Fellows (Pathways to Graduate School)

Immersive research, educational, and mentorship experience for DESU/CU Undergraduates

- ***New pilot program for fully functioning 'pathway/bridge' program in science & engineering***
- Fellowships to support HBCU student research and coursework at UD
- Co-mentored by UD and DESU/CU faculty member
- ***Fellow Seed opportunity to fund DESU/CU mentor to conduct research at UD (facility access with mentee) ****
- Integration with REU summer programming – increased networking
- ***Certificate program development at DESU/CU***

Short-term Outcomes

- ***Enhanced exposure of HBCU undergraduates to materials science***
- Facilitated transition to R1 environment
- ***Increased opportunities to build educational network***
- Increased number of HBCU URGs who effectively pursue graduate-level STEM education

** DESU part of UD's NSF I-Corps Site – close physical proximity of UD/DSU campuses*

Education and Outreach Highlights
Upcoming activities

Research Experience for Undergrads

VENTUREWELL™
idea to impact

Leveraging funding for student I&E training

Expanded Partnerships (e.g., BioPACIFIC MIP)

Future Faculty Workshops

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Thank you

HYBRID MATERIALS INNOVATION - REDEFINING EDUCATION

University of Delaware · NIST · Penn University of Pennsylvania · Delaware State University · Claflin University

National Science Foundation
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