ITUarc
aerospace research center

Nanomaterials, Textiles, and Advanced Composites Research Group

arc.itu.edu.tr

ituarclab ituarclab ituarc

Agenda

- About Us
- Team & Outcomes
- Partnerships & Collaboration

About Us

Aerospace Research Center

ITUarc
aerospace research center

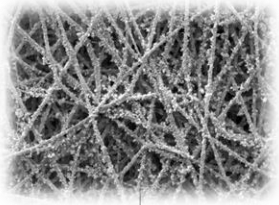
FOCUS

- Nano Engineered & Polymer Composites
- Additive Manufacturing
- 3D Woven Preforms and Composites
- Wearable Electronics

Milestones

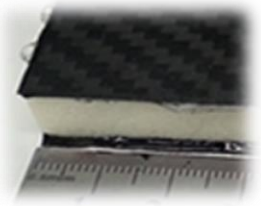
2012 2013 2014 2015 2016 2017 2018 2019 2020

2013 Feb
Boeing-ITU joint
R&D: Nano-Hybrid
Filtration Project

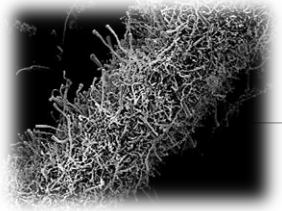


2013
TAI-SSB-ITU joint
R&D: Impact
Properties of
CNT-Carbon
Fiber Reinforced
Composites

2015
Roketsan-ITU joint
R&D: Polymer
Nanocomposite Foams



2016 March
Safran Herakles-ITU joint
R&D: Tailoring Interface
in CMCs



2017
TAI-ITU joint
R&D: Very-Light
Aircraft (VLA)
Design and
Development

2017 Jan
Boeing-ITU joint
R&D: Nano-Composite
Filament for 3D Printers

2017
ITU R&D:
Nanoengineered 3D
Textile Forms

2018 Sep
ITUARC - ISTKA

2018 Oct
Turkish Aerospace
Industry, ITU and Boeing
started Aerospace
Structures and Materials
programme

2019-Hulya CEBECI
TÜBA-The Young
Scientists Award

2018 Oct
International Cooperation
Award from
Turkey Council of Higher
Education to ITU and Boeing

Team & Outcomes

Founders

Assoc. Prof. Hülya Cebeci

Assoc. Prof. Elif Özden Yenigün
(currently at RCA, UK)

Multidisciplinary Team

- Aerospace Engineering
- Materials Engineering
- Textile Engineering
- Chemistry
- Physics

>20

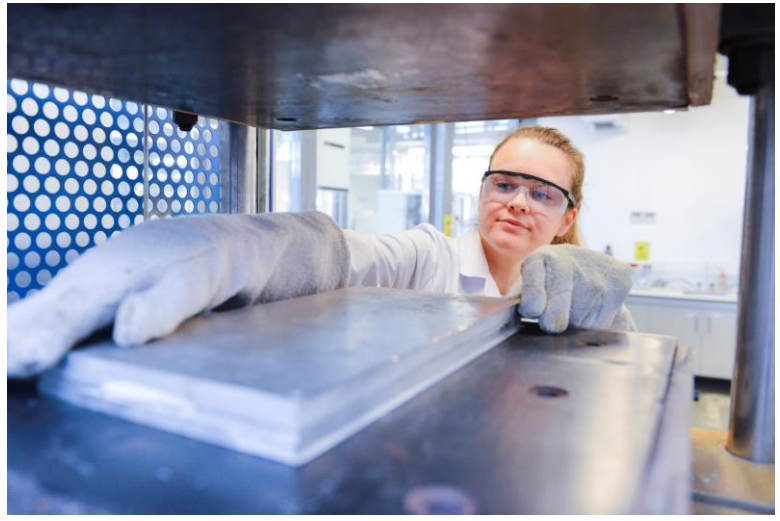
Researchers: Faculty Members, Post-Docs, PhD. Students, M.Sc. Students, Undergrad. Students

1

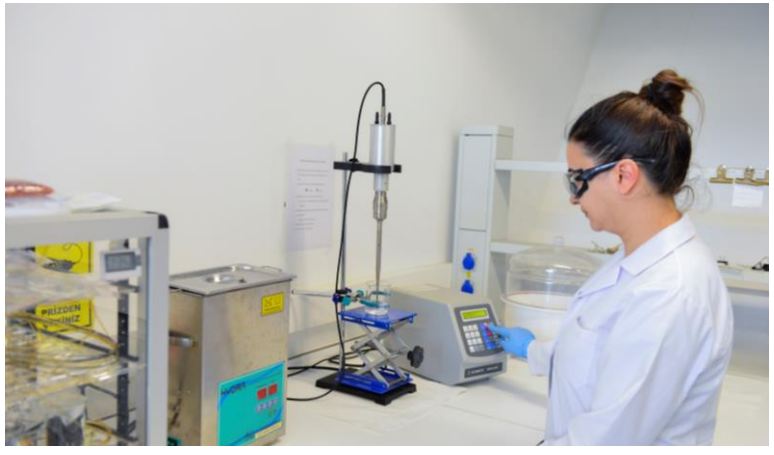
Technician

>20

Alumni (at both industry and academia)




XINKYO



Projects & Intellectual Property

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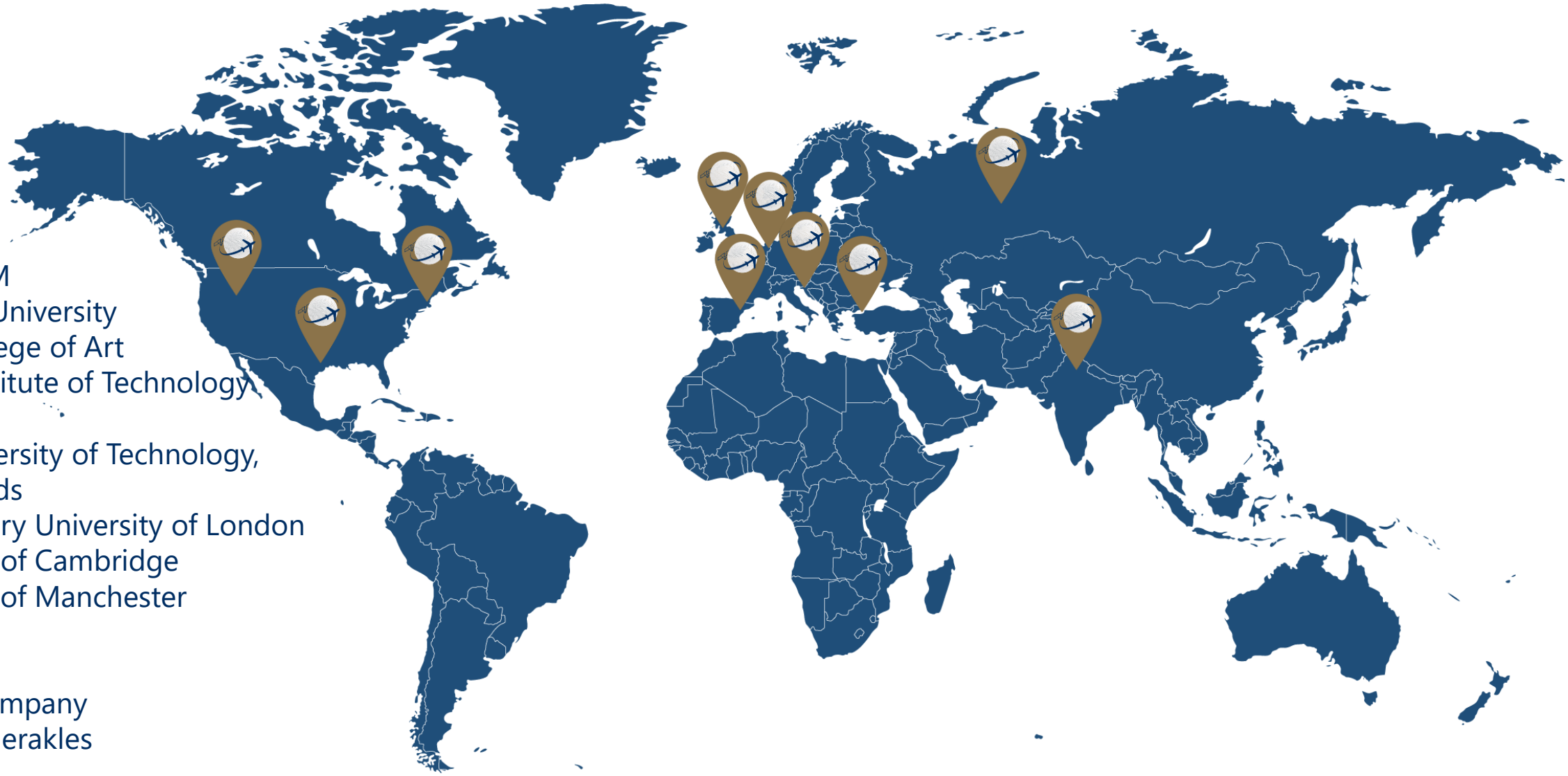
PROJECTS	PUBLICATIONS	PATENTS	CONFERENCES & WORKSHOPS	SPINOFF COMPANY
				ISTAERO AVIATION AND AEROSPACE TECHNOLOGIES
20	38	6	>20	TECHNOLOGY TRANSFER OFFICE

JOURNAL ARTICLES PUBLISHED IN:

- Nature: Scientific Reports
- Advanced Functional Materials
- Composite Science and Technology
- Composite Structures
- Composite Part A & B
- Applied Physics Letter
- Sensors and Actuators A: Physical
- ACS Applied Materials and Interfaces

Partnerships & Collaborations

Worldwide Partnerships



Academic

- MIT
- Texas A&M
- Cranfield University
- Royal College of Art
- Indian Institute of Technology Delhi
- Delft University of Technology, Netherlands
- Queen Mary University of London
- University of Cambridge
- University of Manchester

Industry

- Boeing Company
- SAFRAN Herakles
- TNO

National Partnerships

Academic

- TUBITAK
- Sabanci University
- Middle East Technical University
- Yalova University

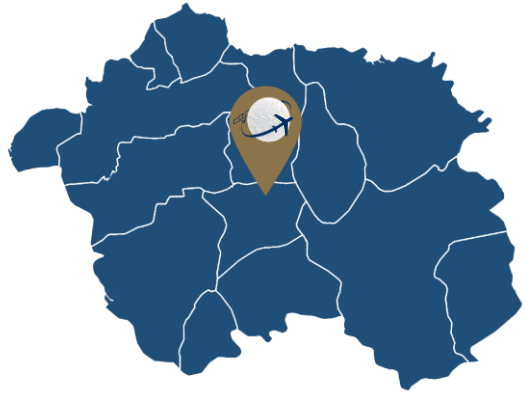
Industry

- ROKETSAN
- TAI
- ASELSAN
- EPSAN

Yalova

Istanbul

Ankara



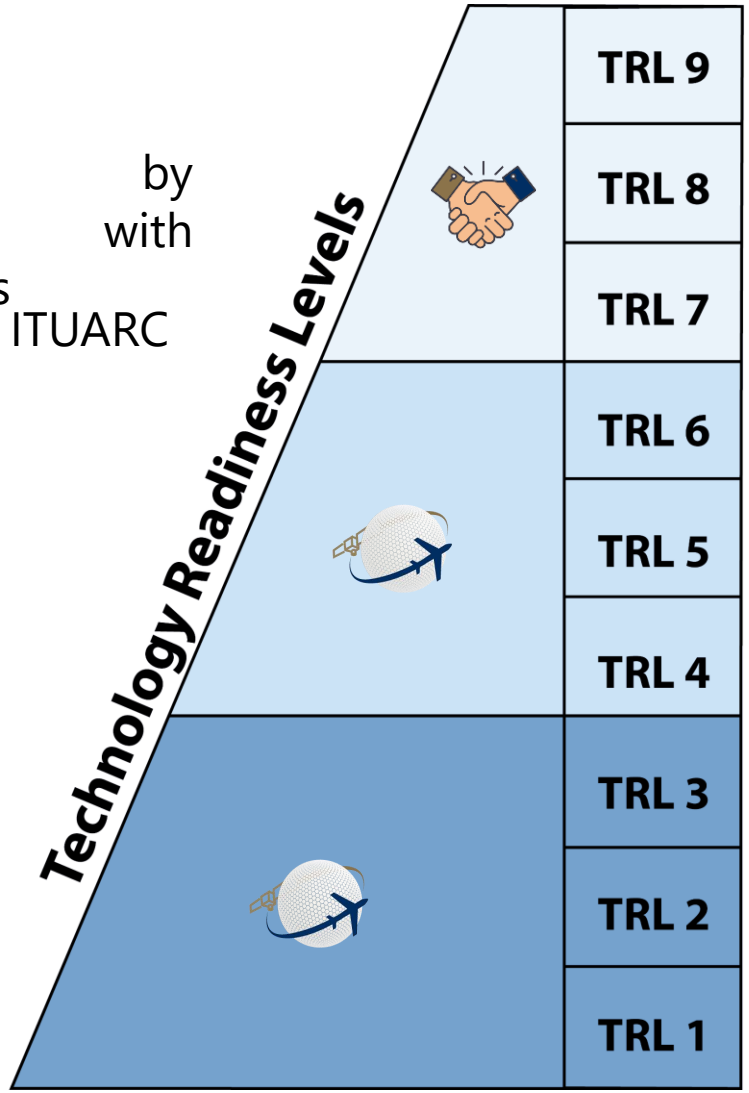
Eskisehir

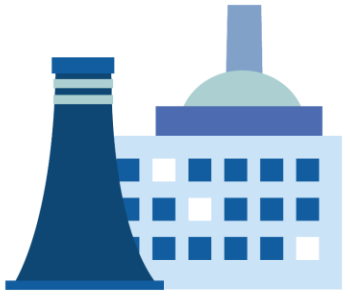
Forms of Collaboration

Technology Readiness Levels

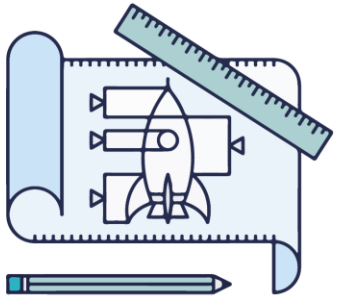
Achievable by collaboration with industrial partners

Achievable within ITUARC





System/Subsystem Development and Test&Operations



Technology Development and Demonstration

Basic Technology Research and Feasibility Proof

FOCUS

- Nano Engineered & Polymer Composites
- Additive Manufacturing
- 3D Woven Preforms and Composites
- Wearable Electronics

Nano Engineered & Polymer Composites

Nano Engineered and Polymer Composites
Nanomaterials Synthesis

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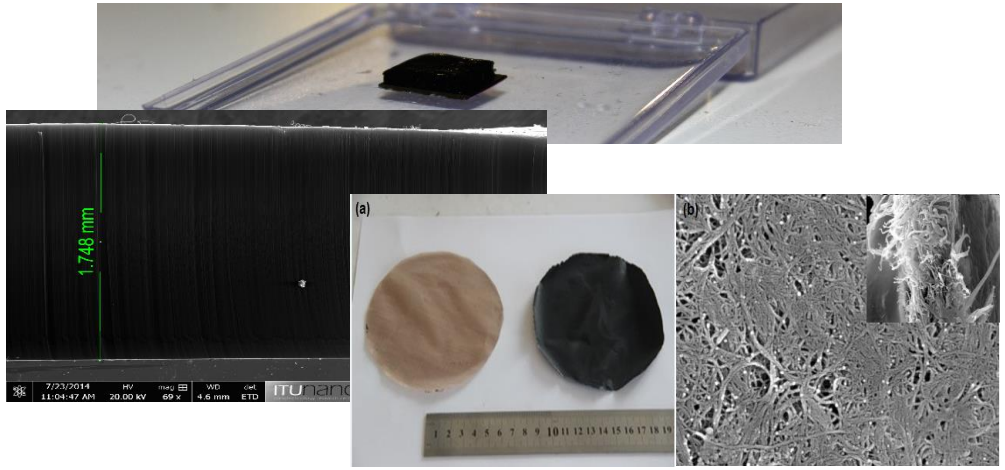
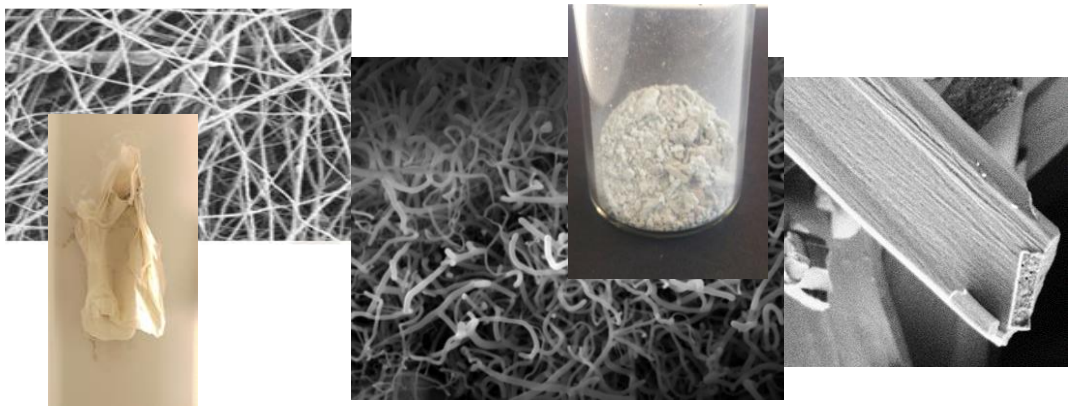
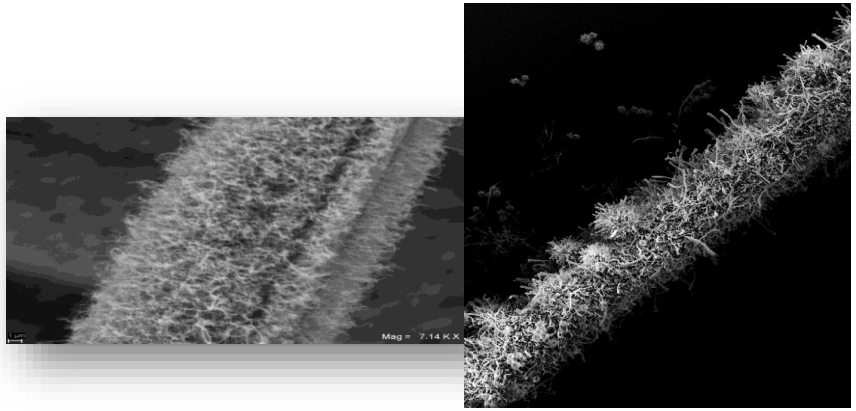
Carbon Nanotubes (CNTs) and CNT Buckypaper



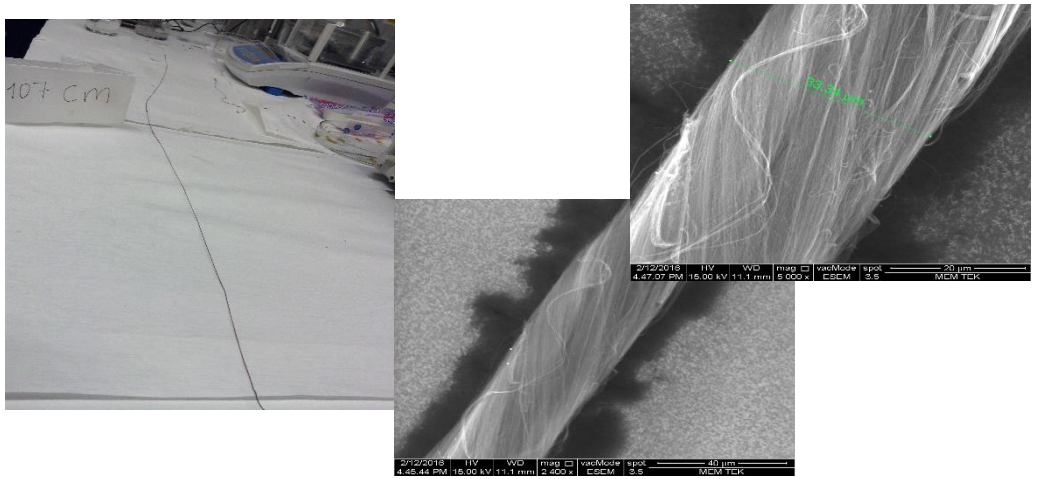
Boron Nitride Nanomaterials: Nanotubes (BNNTs) Nanofibers (BNNFs), Nanosheets (BNNSs)



Carbon Nanotube and Boron Nitride Nanotube onto Fibers



Graphene and CNT Yarn



Nano Engineered and Polymer Composites: Interface Engineering

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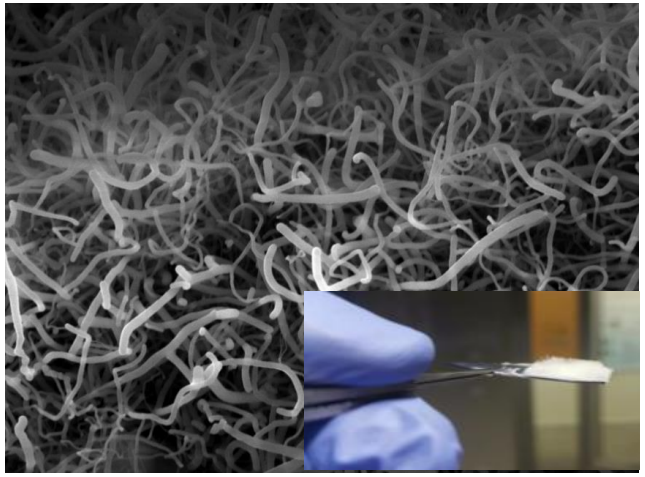
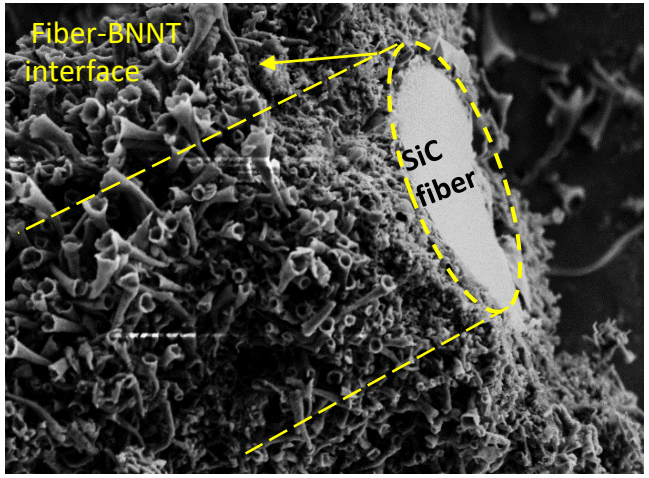
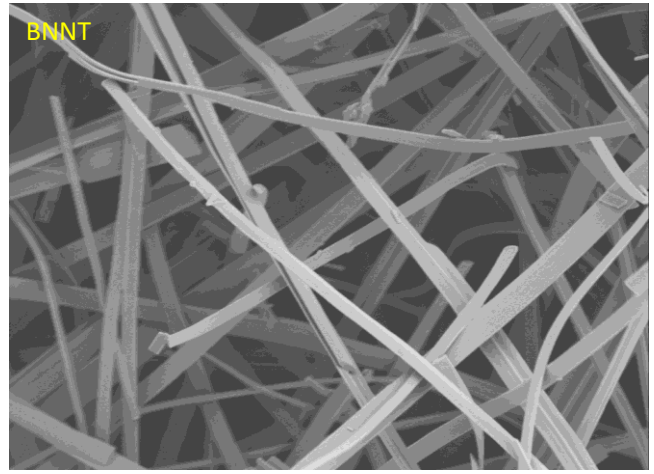
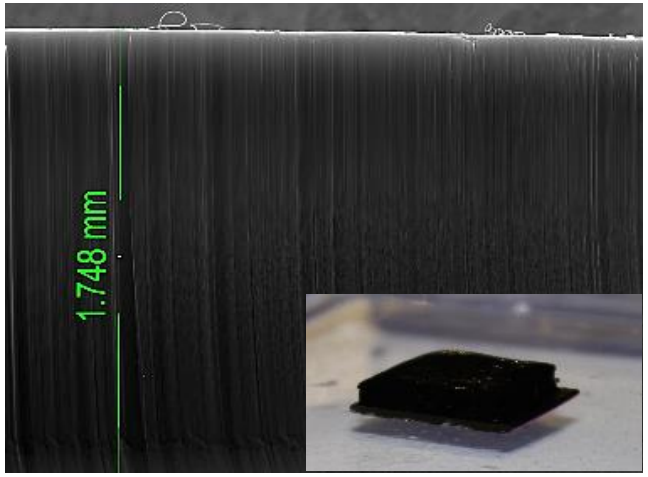
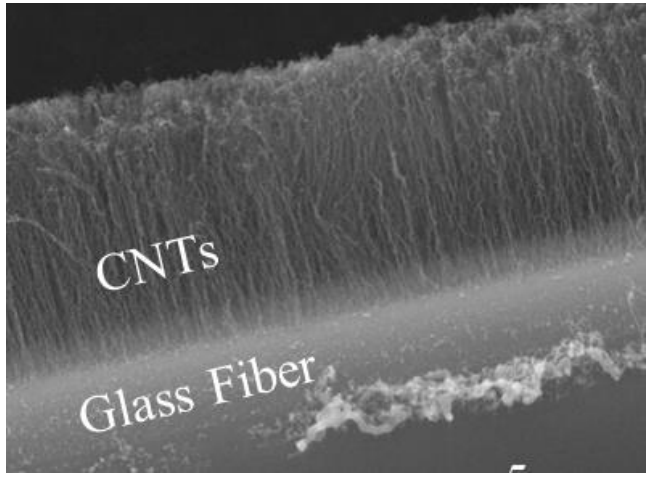
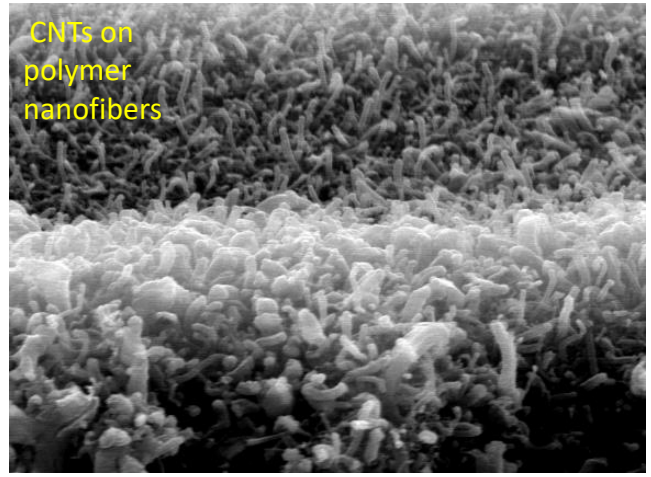
	Si wafer	Micro-scale fibers (ceramic, carbon and glass)	Nanofibrous fibers (ceramic and polymer)
BN based			
Carbon based			

Nano Engineered and Polymer Composites

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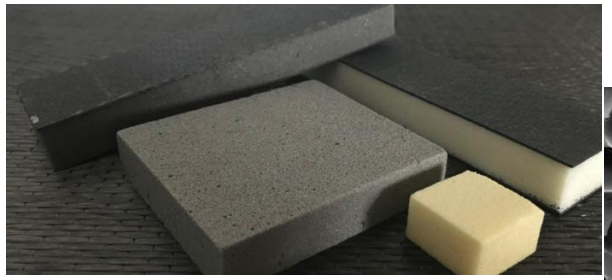
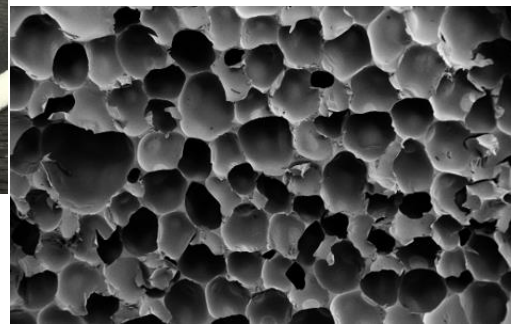
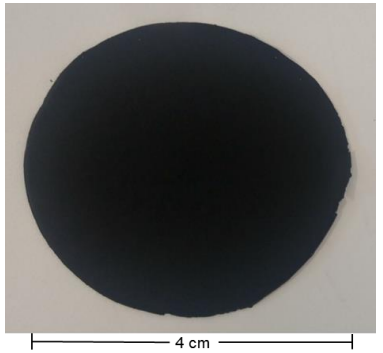
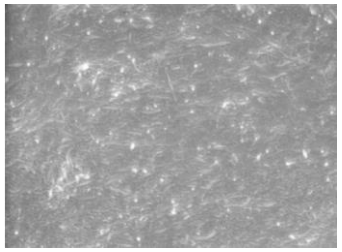
Polyurethane (PU) foams/ CNT, shear thickening fluid (STF) reinforced sandwich composite

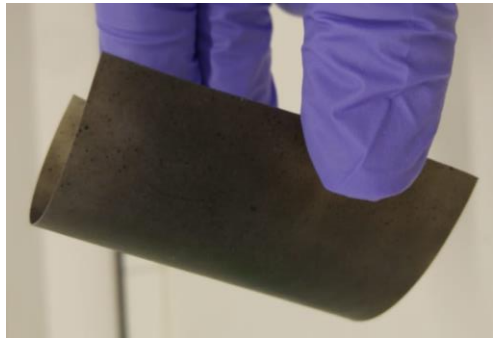




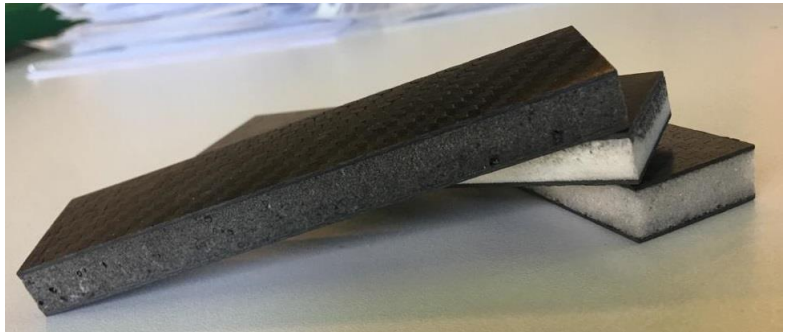
CNT buckypaper reinforced high density polyethylene (HDPE) laminated nanocomposite

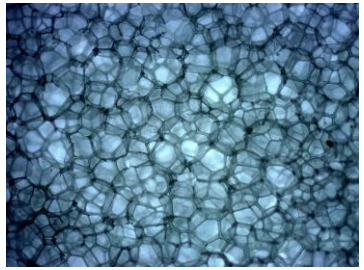






Functional Foams: Polymethacrylimide (PMI) foams/ CNT reinforced sandwich composite





BN and BN/CNT reinforced Polyetherimide (PEI) reinforced polymer nanocomposite

Functional Foams: By Nanofillers for Tailoring PU properties

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Motivation: To improve mechanical properties of PU foams in different aspects including:

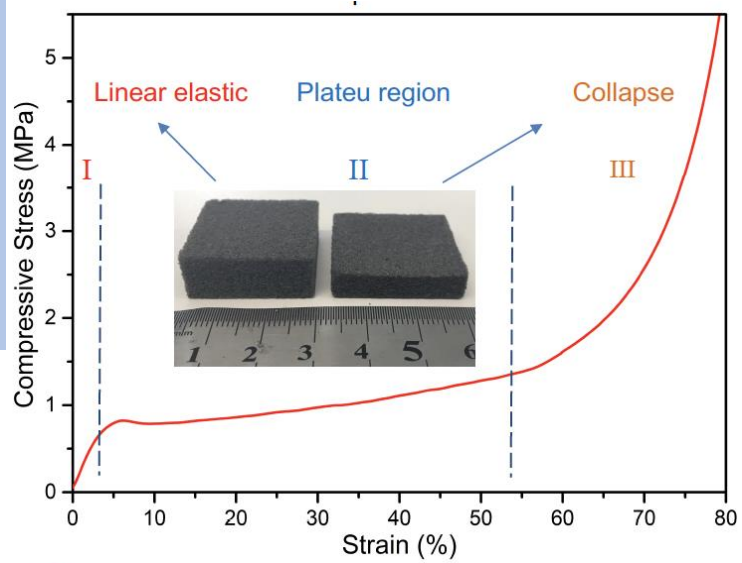
- Compressive strength and modulus
- Flexural strength and modulus (in sandwich composite applications)
- Impact strength and resistance
- Energy absorption and damping capabilities

with an aim to their use in aerospace applications as sandwich composites, replacing honeycomb

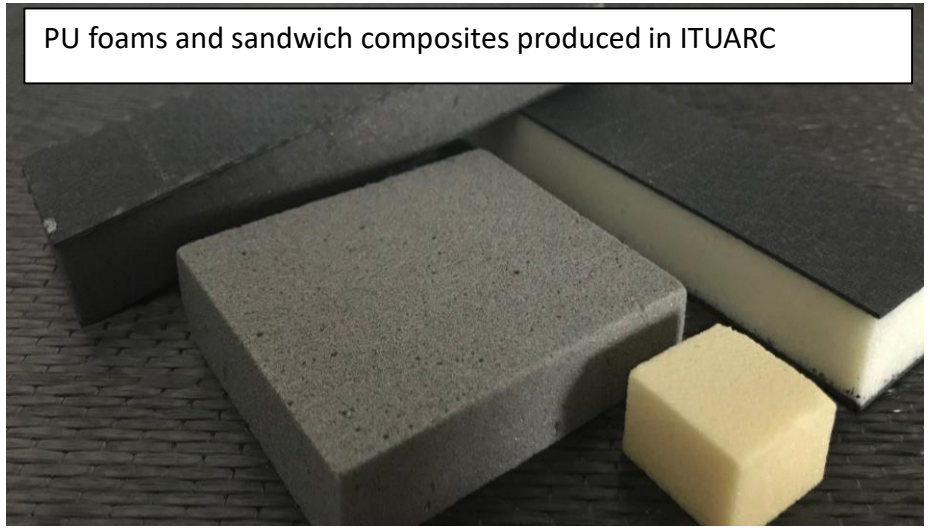
Reinforcing agents:

- Carbon nanotubes (CNT) → **enhanced compressive behavior**
- Shear Thickening Fluids (STF) → **improved impact strength and damping**

Typical stress-strain behavior of rigid PU foam under compressive load

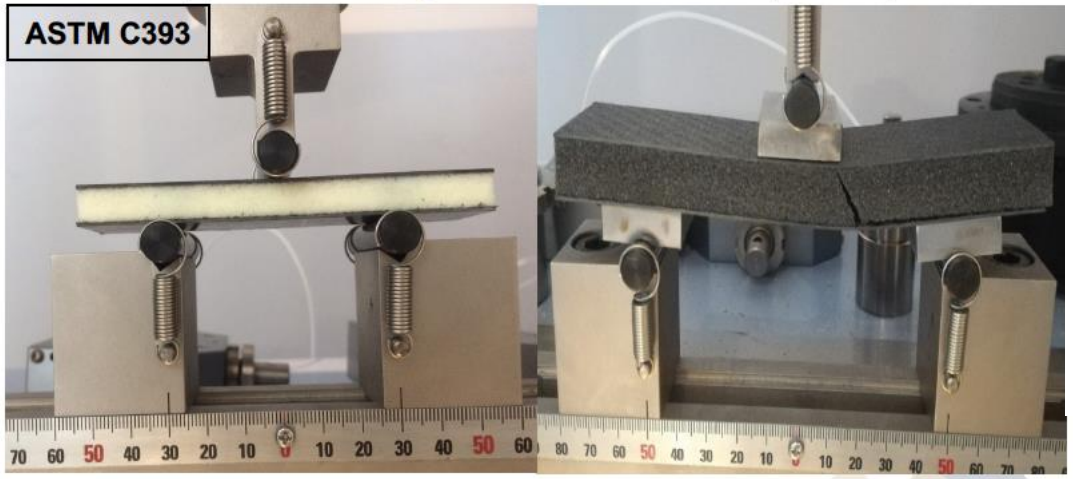


PU foams and sandwich composites produced in ITUARC



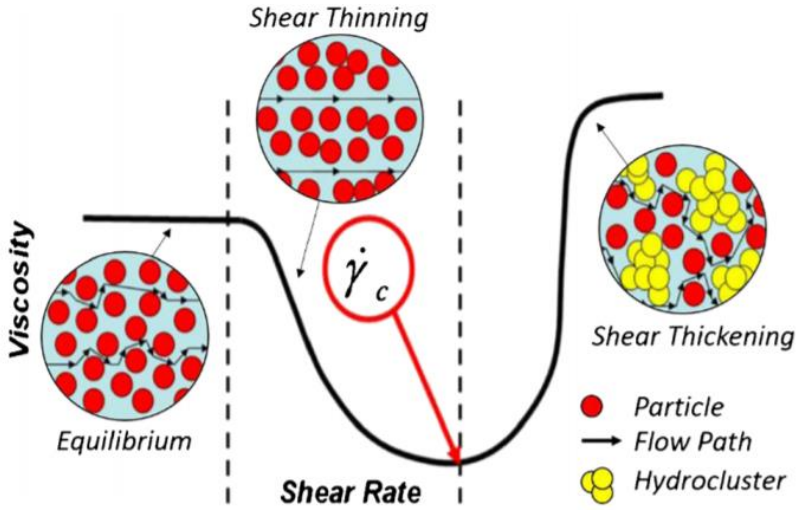
Roller supports and loading bar

Aluminum pads on pivots

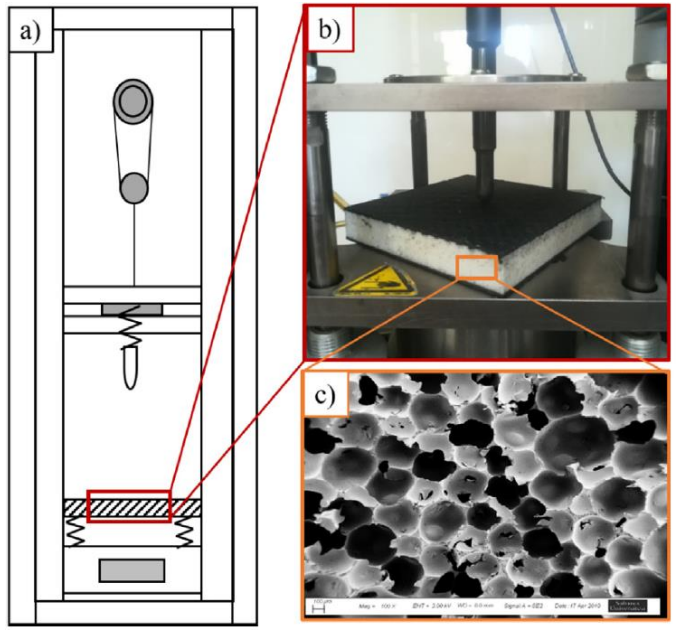


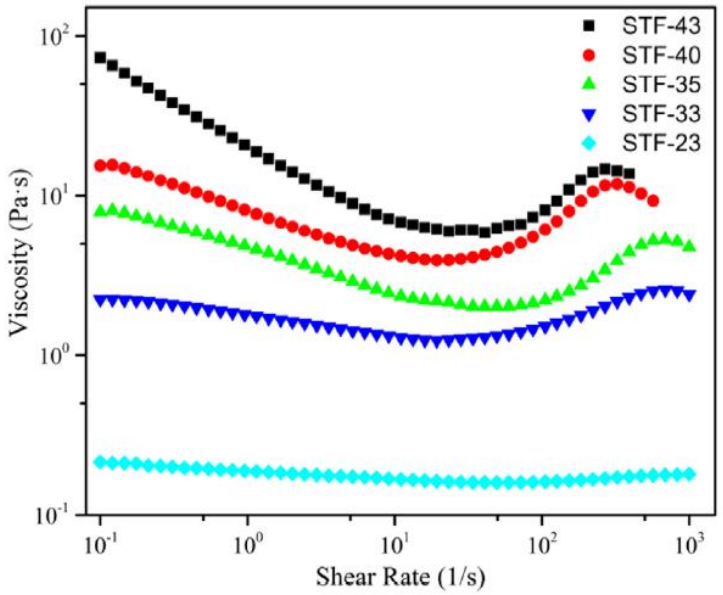
- Localized damages/cracks seen under cylindrical loading pivot
  - Not acceptable through ASTM standards.
- True failure mechanism seen within aluminum pads
- Enhancement in ultimate core shear stress at least 28%
- Enhancement in facing stress at least 33%

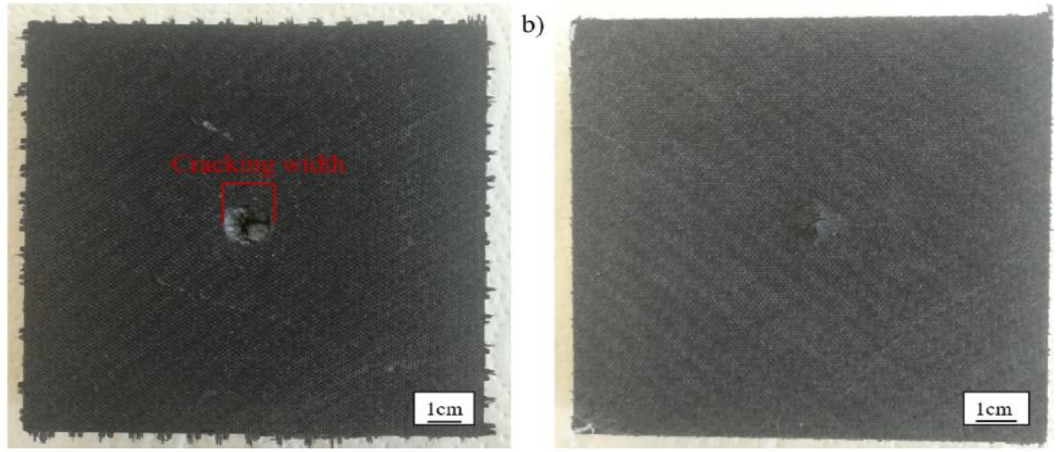
Functional Foams: By Shear Thickening Fluid Fillers for Tailoring PU properties



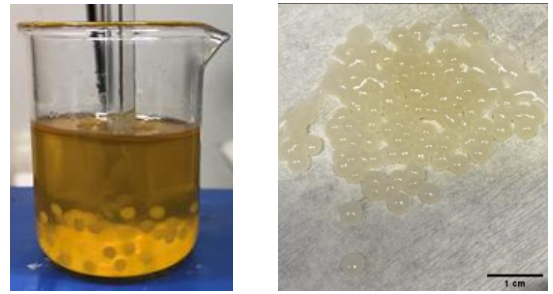
- Reveal the effects of STFs on PU cell morphology
- Oriented particles, easy flow and reduced viscosity at low shear rates
- Hydroclustering, resistance to flow and increased viscosity at high shear rates







Impact response of STF-filled polymeric foams



- Microstructure of STF-filled PU foam
- Enhanced impact performance
- Lower damage

Polymethacrylimide (PMI) Foams: A high performance applications

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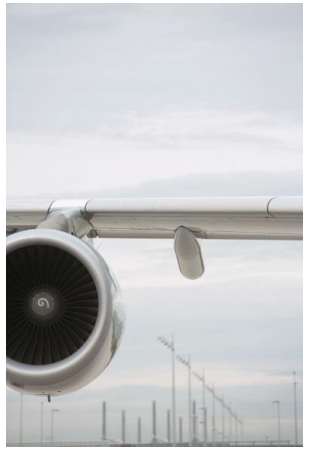
Closed cell polymeric foams have great potential with;

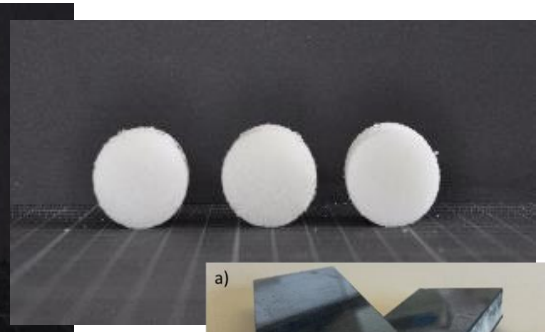
- High surface area and closed cell geometry, which bring well adhesion between face sheets,
- Low cost, lightweight,
- High specific strength, and
- High corrosion resistivity.

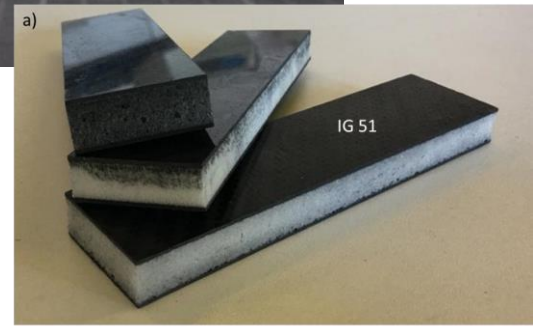
PMI foam is started to be used in aerospace industry as structural sandwich core (*e.g.*for helicopter blades).

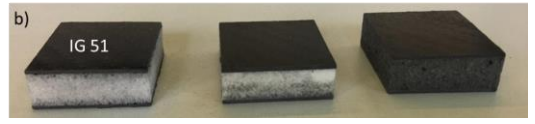
Commercial PMI major supplier: Evonik Industries

- High specific strength and modulus,
- Heat resistance and post curing temperatures up to 225ºC,
- Cost saving in core shaping and processing,
- Lower moisture uptake of PMI cored sandwich panels.









CNT Smart Paint & Future Applications

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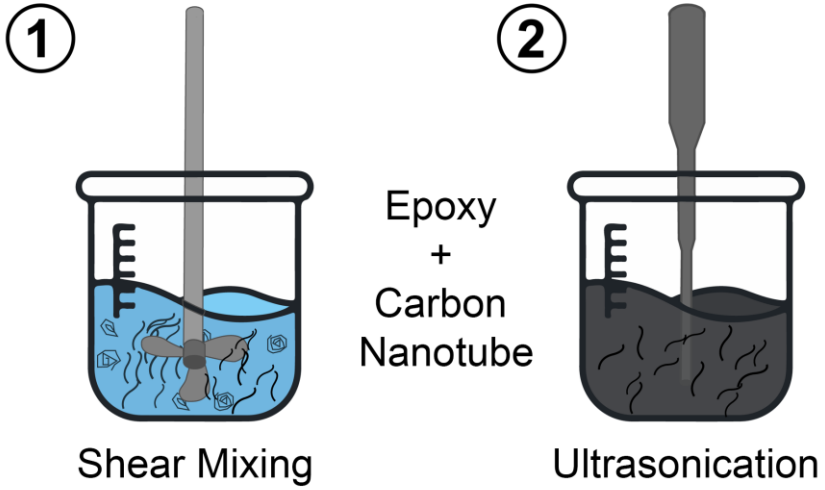
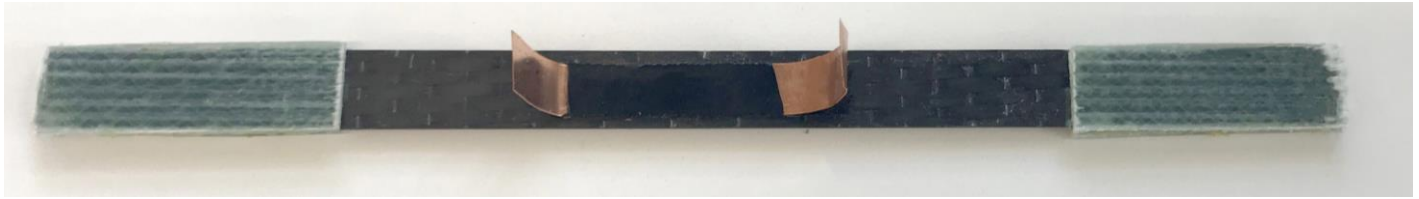
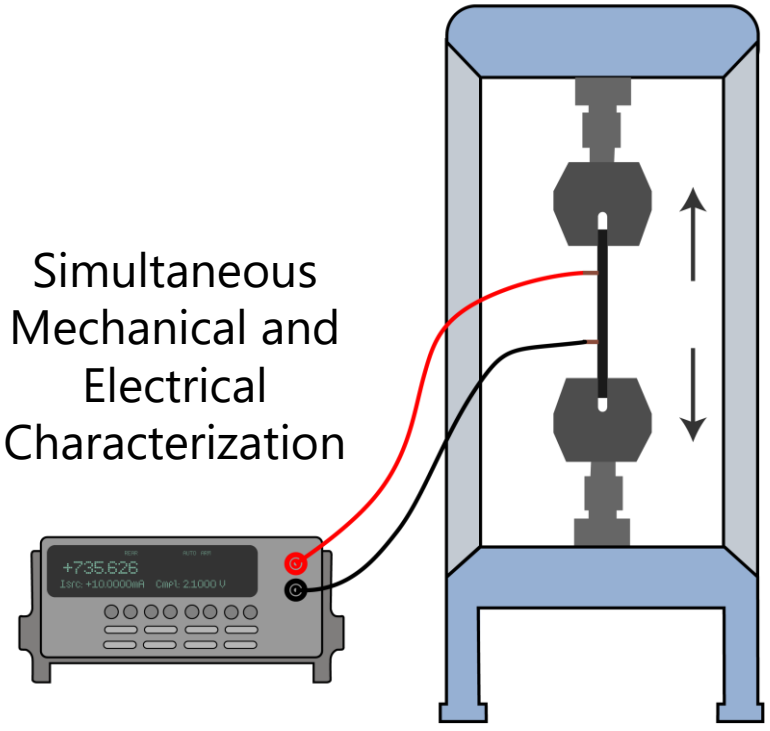
Fabrication of CNT Smart Paint





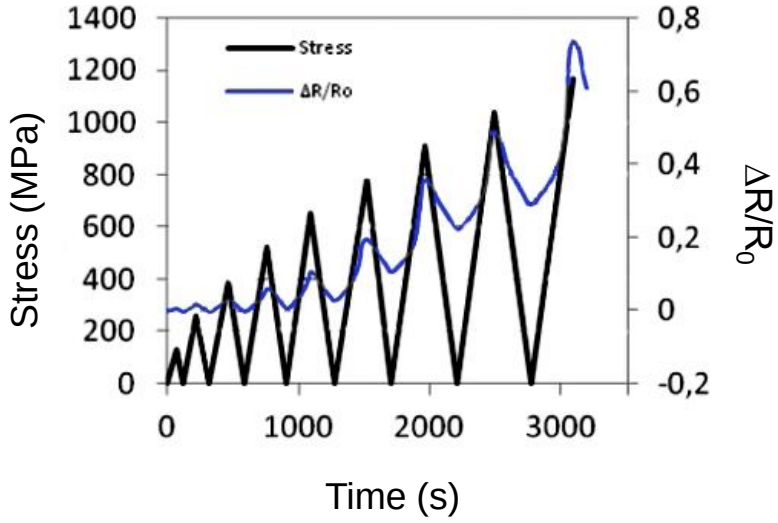
Simultaneous Mechanical and Electrical Characterization



Source Meter with picoampere sensitivity

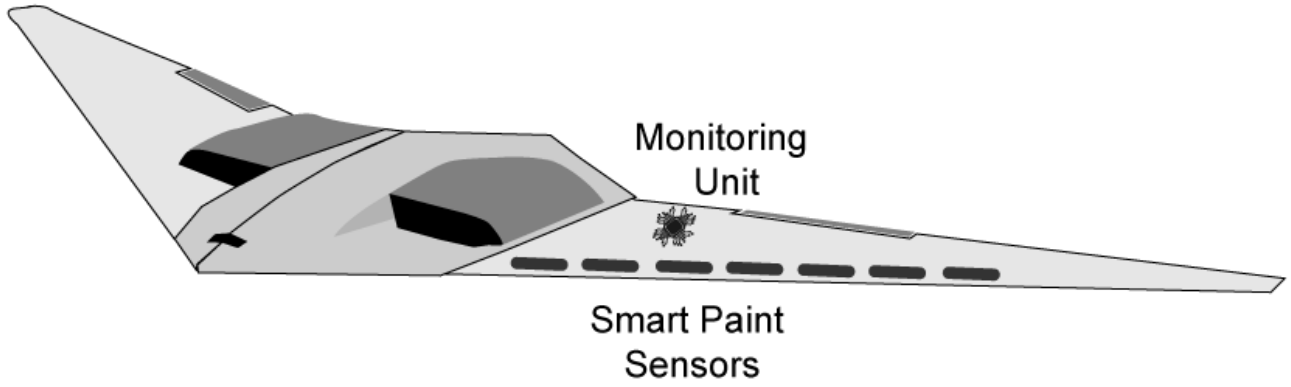
Universal Test Machine (UTM)

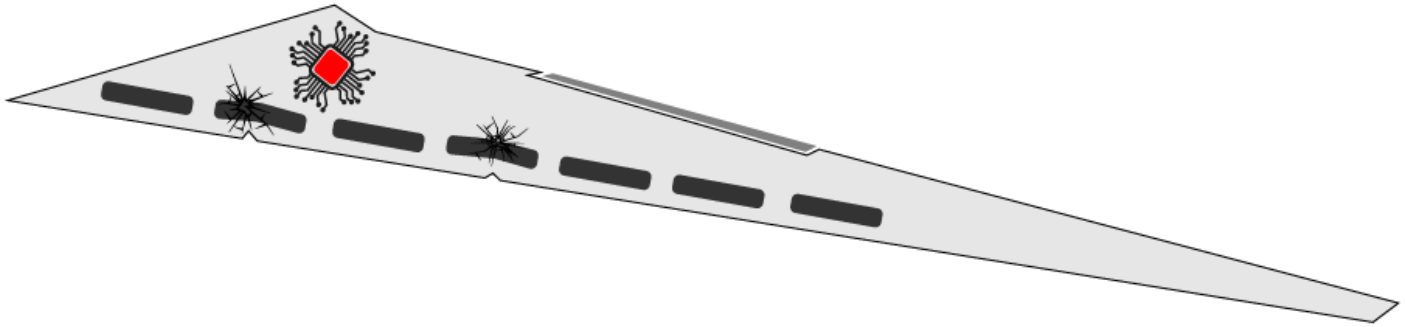
Loading-unloading testing: stress & $\Delta R/R_0$ vs. time graph for CNT smart paint



CNT Smart Paint & Future Applications

Motivation: Lightweight nano material based smart sensors designed for aerial vehicles.



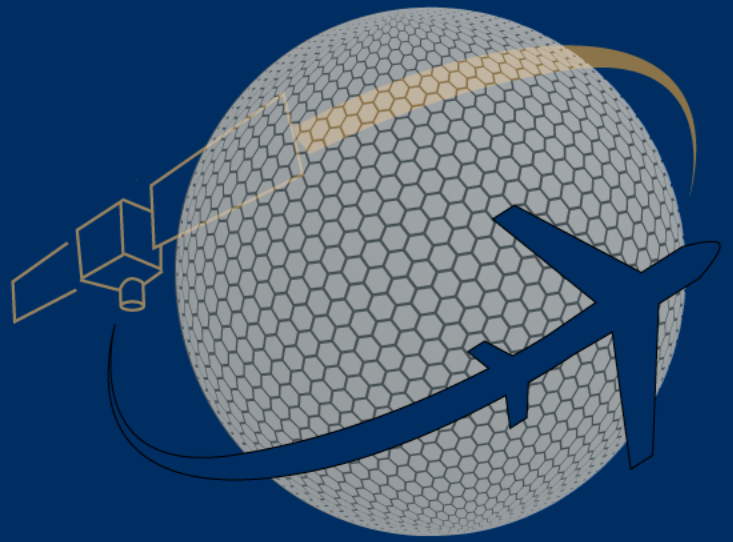


Real Time Monitoring

No Weight Penalty
& Multifunctionality

Damage Detection
& Early Warning

Nano Engineered & Polymer Composites Applications



- In extreme conditions
- For radiation shielding
- For thermal management
- In laminated/sandwich composites
- In structural lightweight composites
- For structural health monitoring
- In Cryogenic conditions

Textiles: 3D Woven Preforms and 3D Composites & Wearable Electronics

Manufacturing 3D woven I, T Profiled Beams and Monocoque Airfoil Shaped Structural Composites

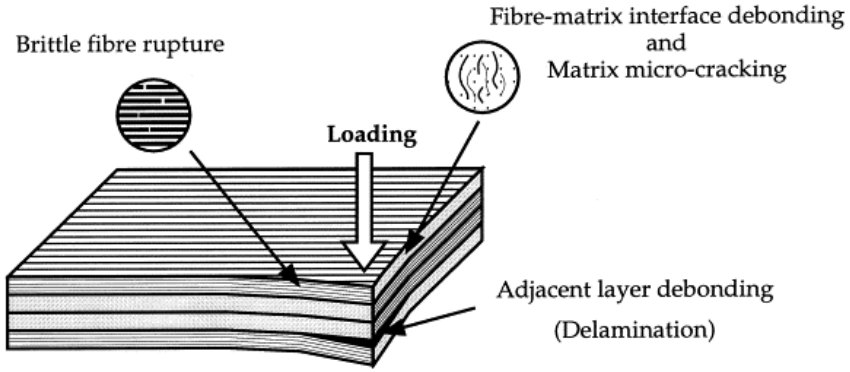
Motivation:

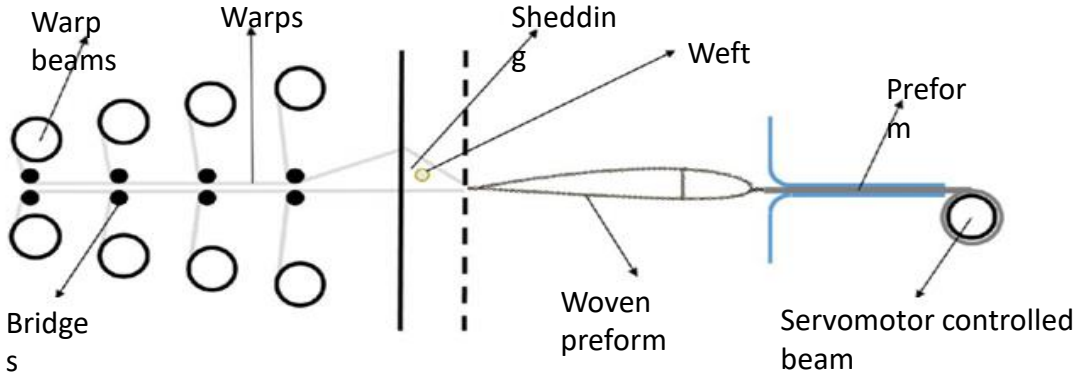
- Improving the delamination (separation of layers) resistance which is the major disadvantages of the laminated structures.

- An innovative production line to manufacture 3D woven composites, for aerospace structure.

- Manufacturing complex shaped integrated preforms like un-manned air vehicle (UAV) airfoil with the final product shape which will reduce the weight while improving the impact and flexural properties.

- Improving the impact resistance to possible bird strike and operational loading.



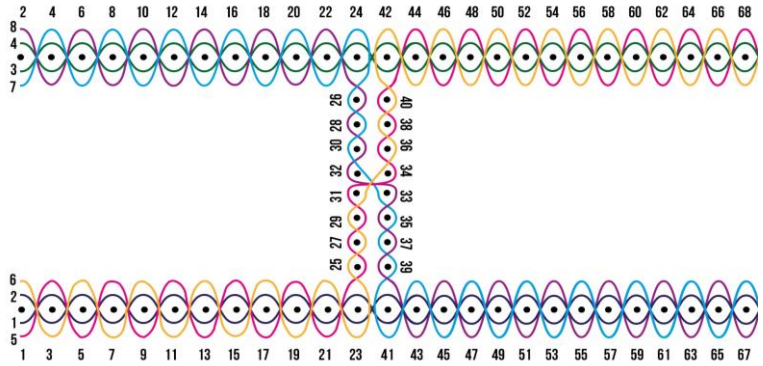


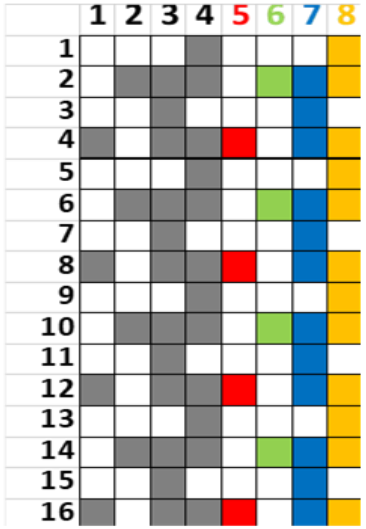
Airfoil weaving design

Manufacturing 3D woven I, T Profiled Beams and Monocoque Airfoil Shaped Structural Composites

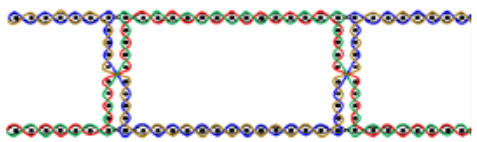
ITUarc aerospace research center

3D Preform Design





Dobby Plan



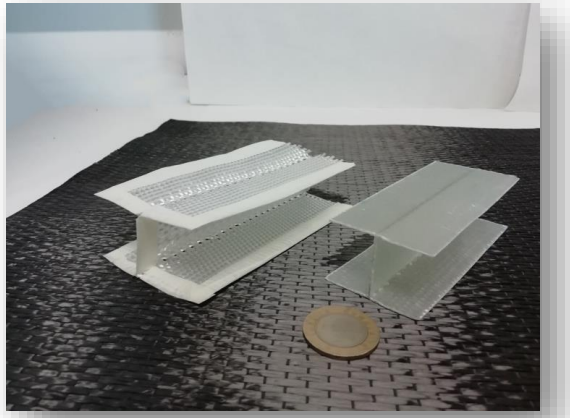
Rectangular Fabric

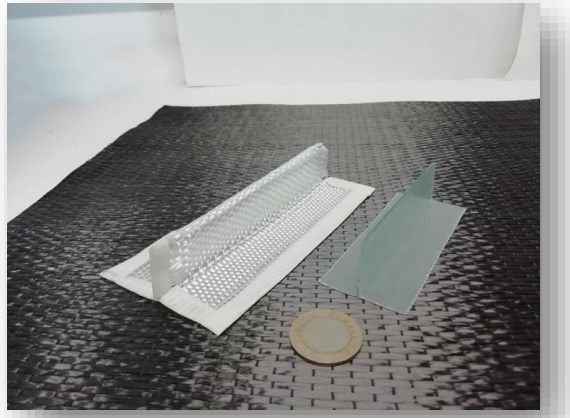
T Beam Fabric Design

Airfoil Fabric Design

3D Weaving

3D Composites





Manufacturing 3D woven I, T Profiled Beams and Monocoque Airfoil Shaped Structural Composites

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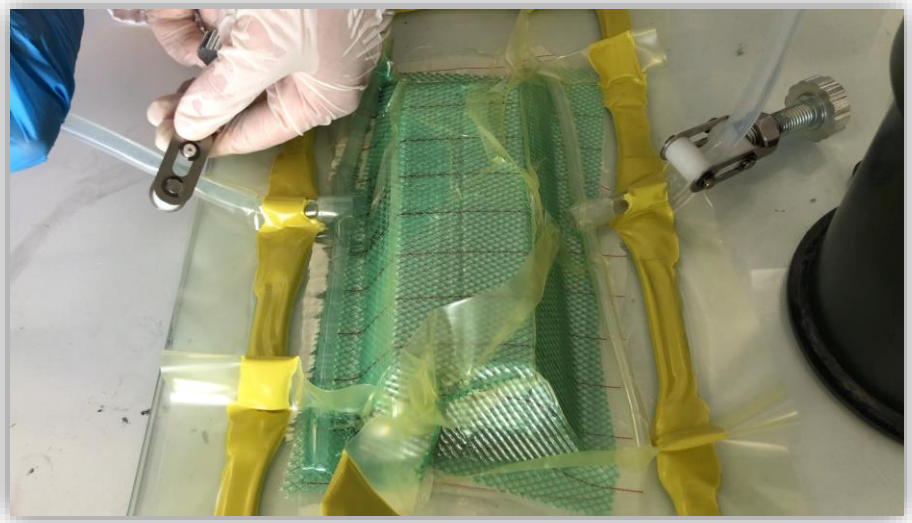
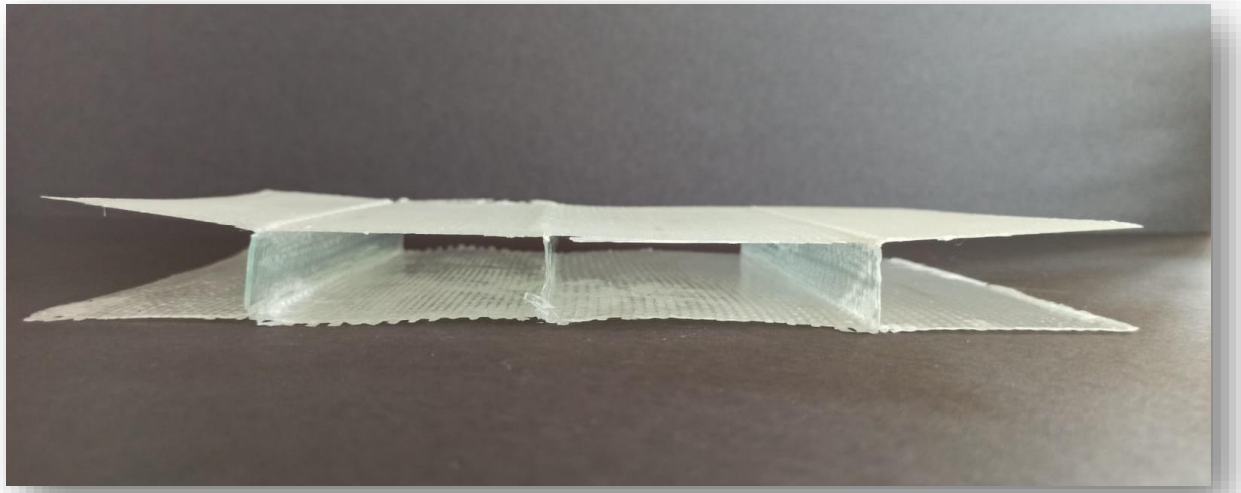
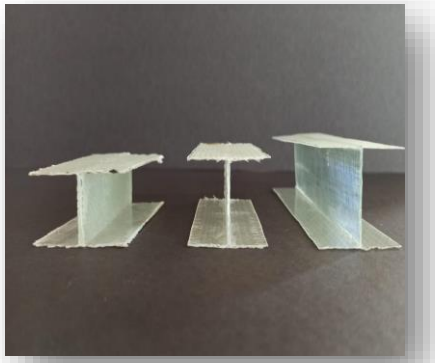
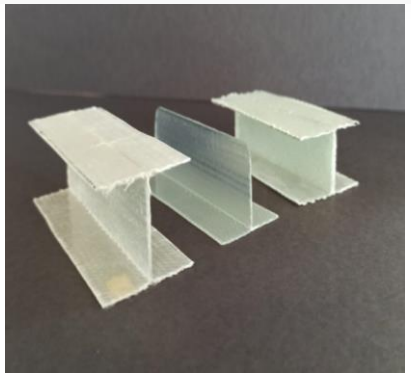
Novel Solutions to 3D Woven Composites

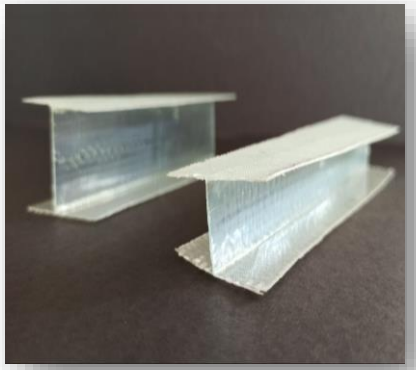




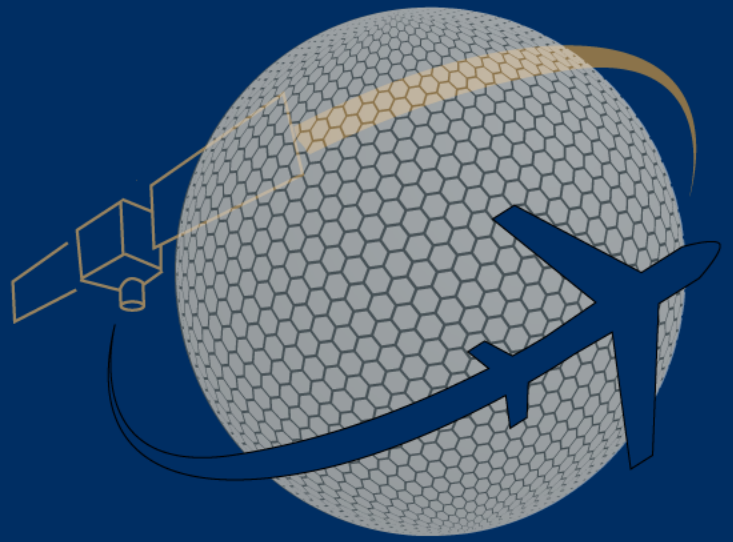
- A novel mold design for composite manufacturing.
- Minimum void content is target!
- Tailorable epoxy properties for high quality composites.
- High fiber volume fraction.







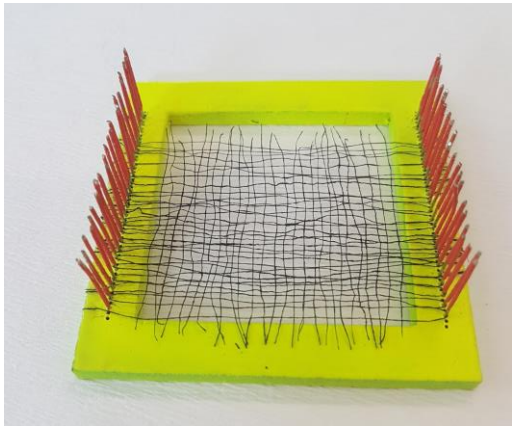
Wearable Electronics



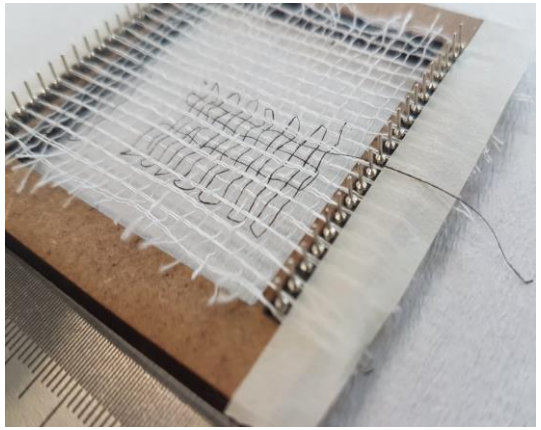
WEARABLE SYSTEMS

- Meters long, continuous and uniform fibers
- Sensing, supercapacitor, antenna designs applications

Weaving (5x5 cm^2)



Integration into the cloth (5x5 cm^2)

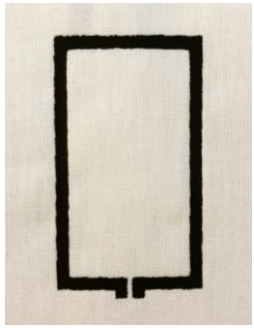


Meters long graphene oxide fibers

Textile antenna designs prepared by CNT-based electrical conductive inks

σ=20.4 S/cm

PICA design



σ=5.2 S/cm

LOOP design

Wearable Electronics: CNT and Graphene Sensor & Antenna Systems

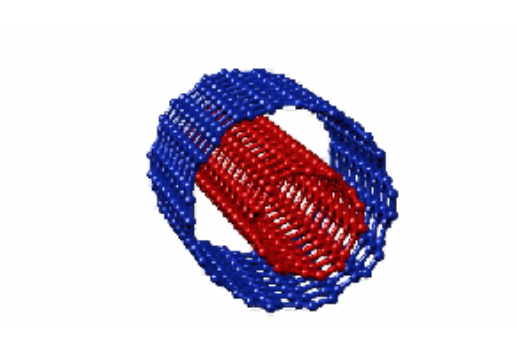
ITUarc aerospace research center

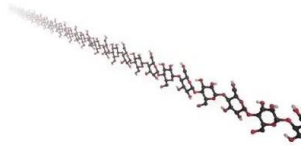
<u>Motivation:</u>

- Metal-free, polymer free, water-based, lower design complexity, fabrication ease, integration of an environment-friendly

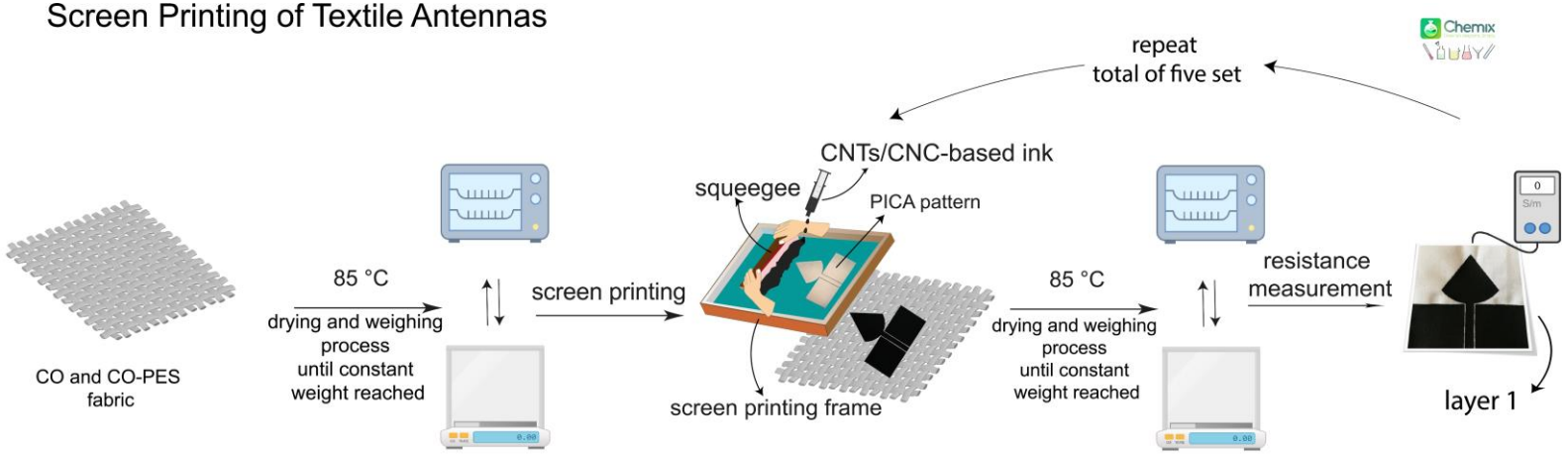
<u>Aim:</u>

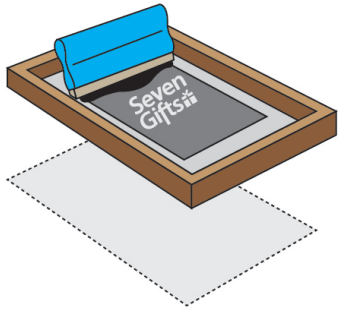
- The main objective of this study is to develop CNTs/CNC-based antennas for smart textiles that push the state-of-the-art in wearable communication, by utilizing traditional textile manufacturing techniques.

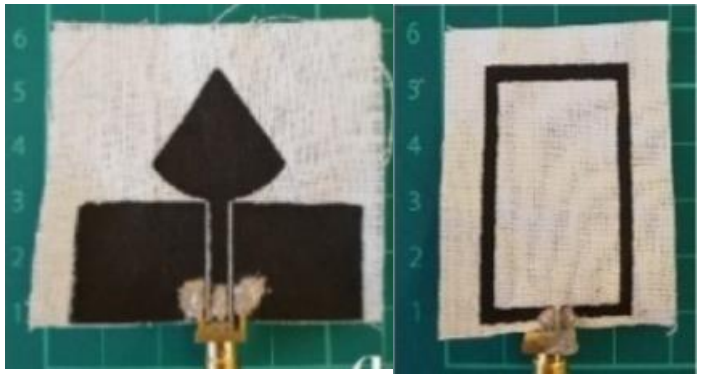




Screen Printing of Textile Antennas





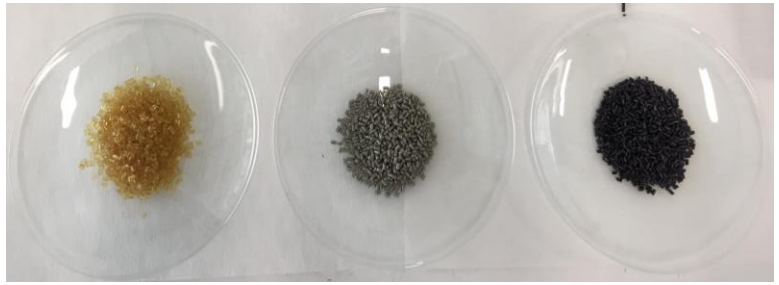


- Two different fabric-based antenna designs called PICA and LOOP
- The fabric prototypes were tested in dynamic environments and tested for washing or ironing
- Electrical conductivity up tp 20.5 S/cm
- PICA bandwidth (on-body) up to 9 GHz, LOOP bandwidth (on-body) up to 2.5 GHz

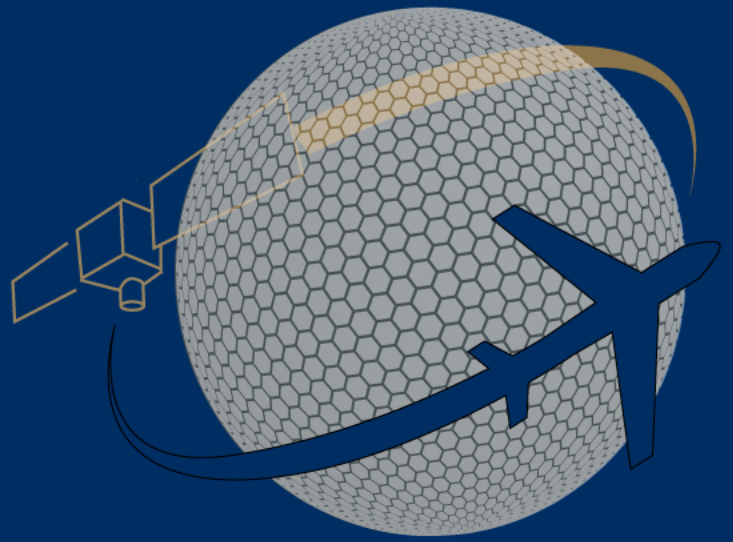
Additive Manufacturing

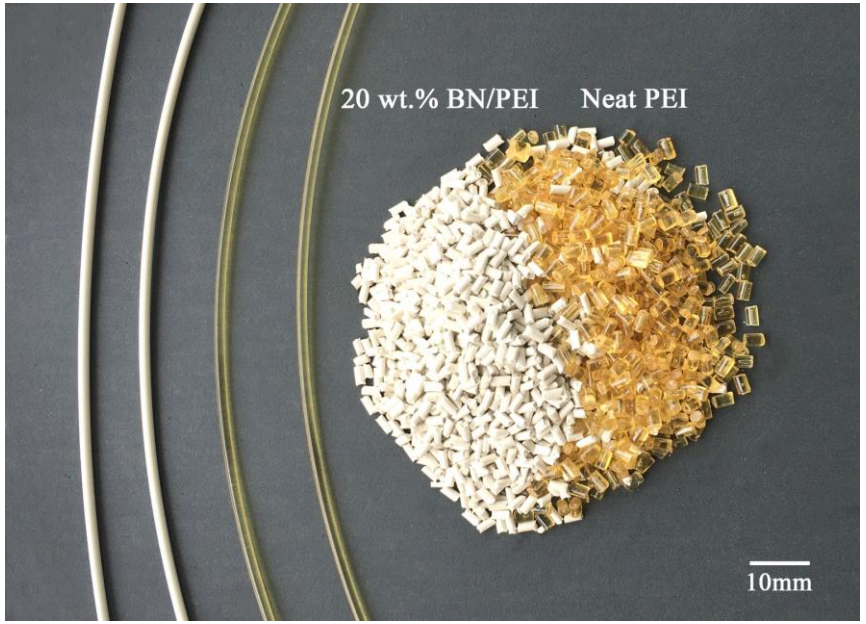
Melt Processing of High Performance Polymers

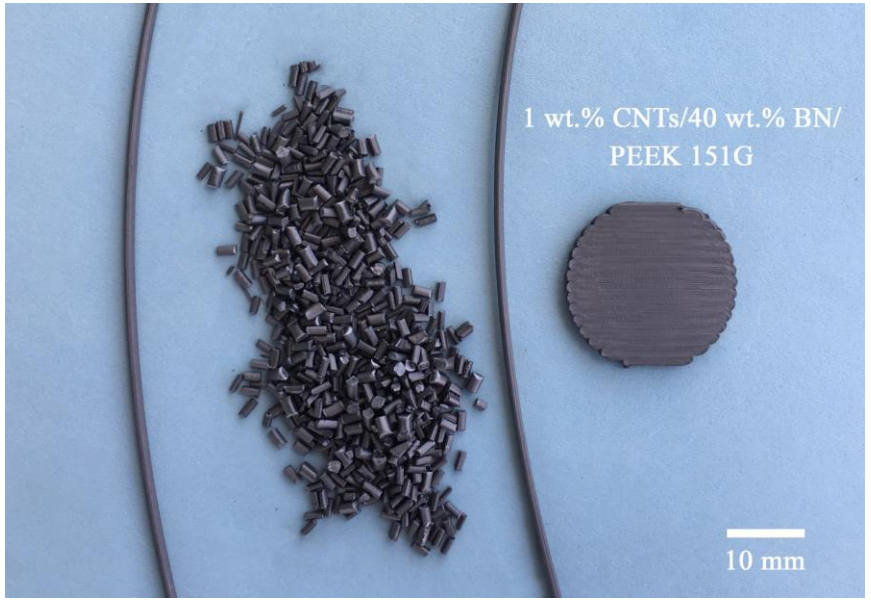
Aim: To develop high performance polymeric filaments such as PEI, PEEK thermoplastics by melt processing for additive manufacturing.

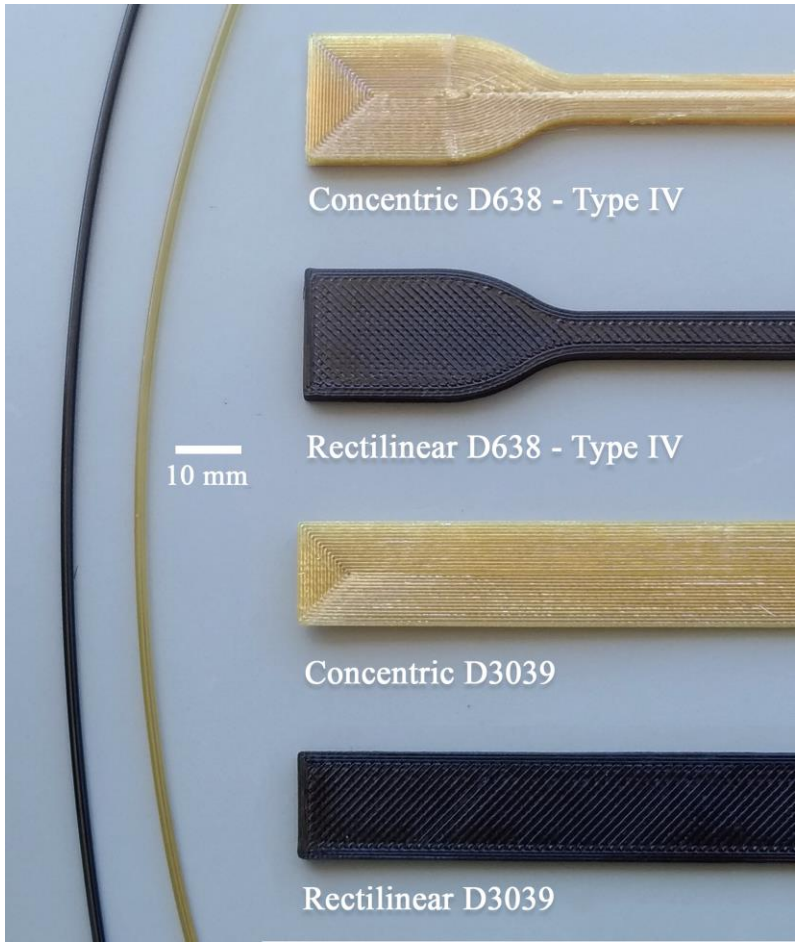


Melt Processing of High Performance Polymers





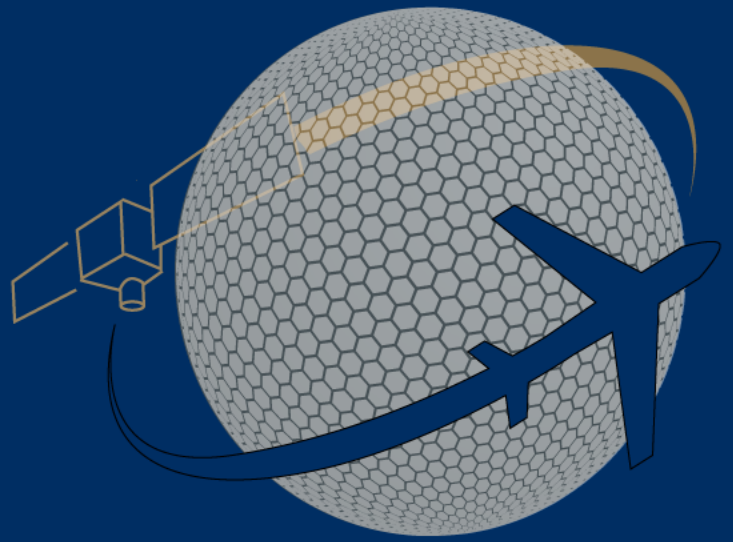




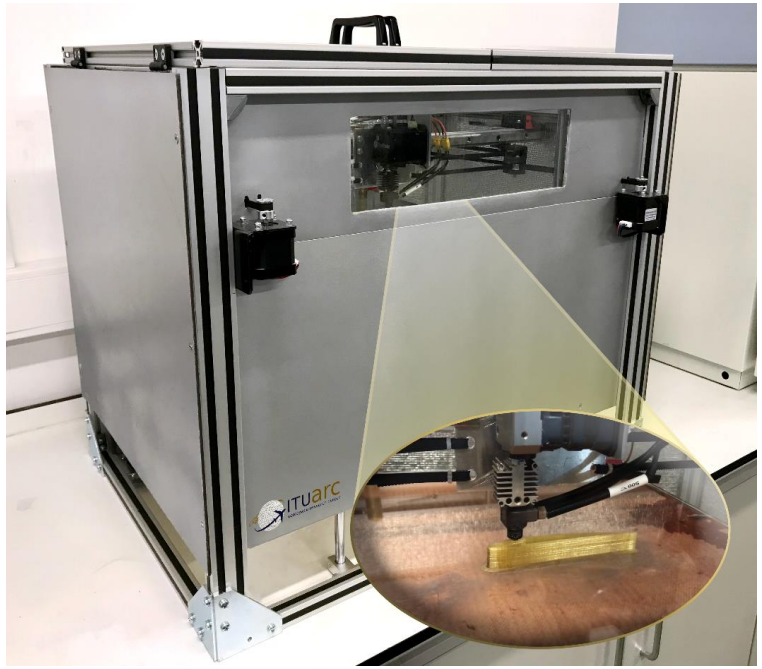
Different type of test specimens produced by 3D Printer with Neat PEI and CNTs/PEI filaments

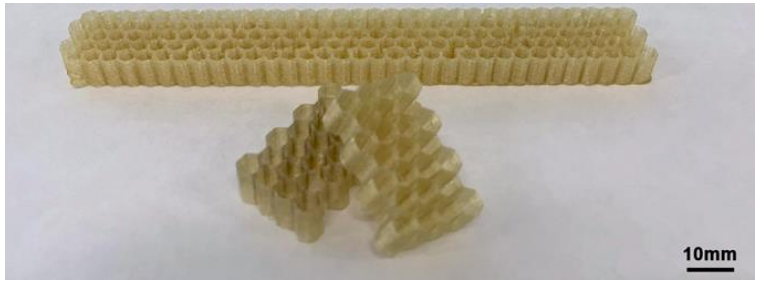
Additive Manufacturing:

Fused Filament Fabrication (FFF)

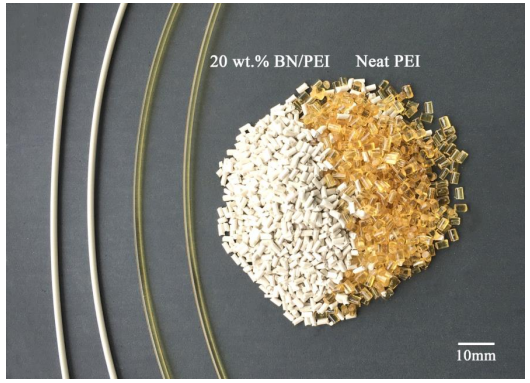


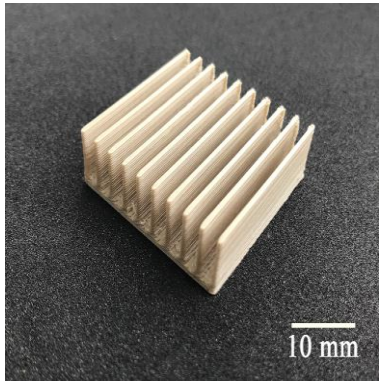
3D Printer Designs (high printing temperature up to 400 °C)

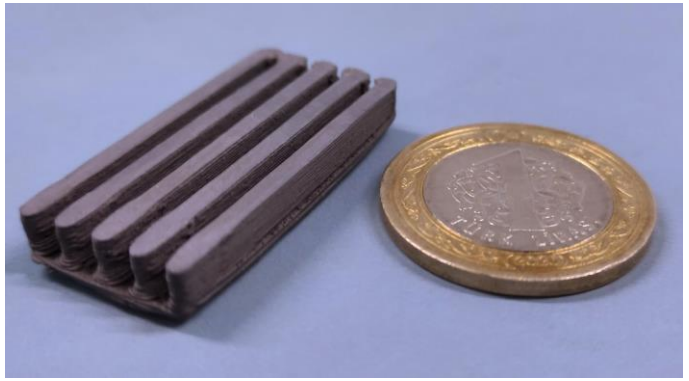




3D Printing Products



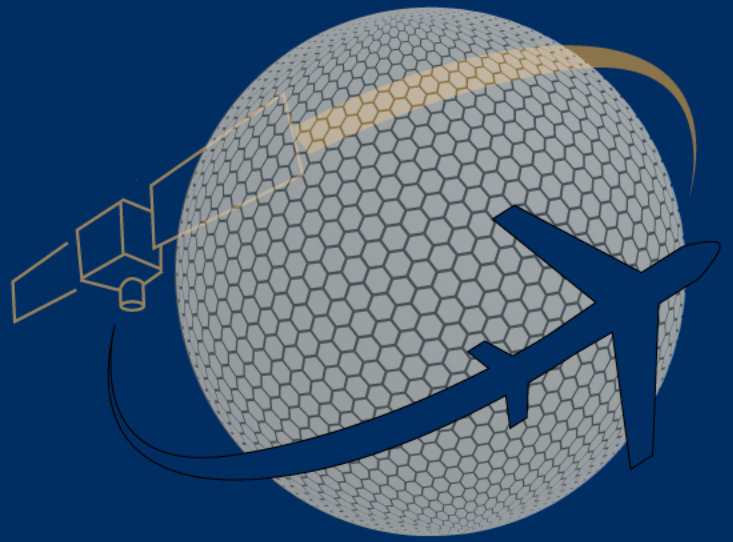


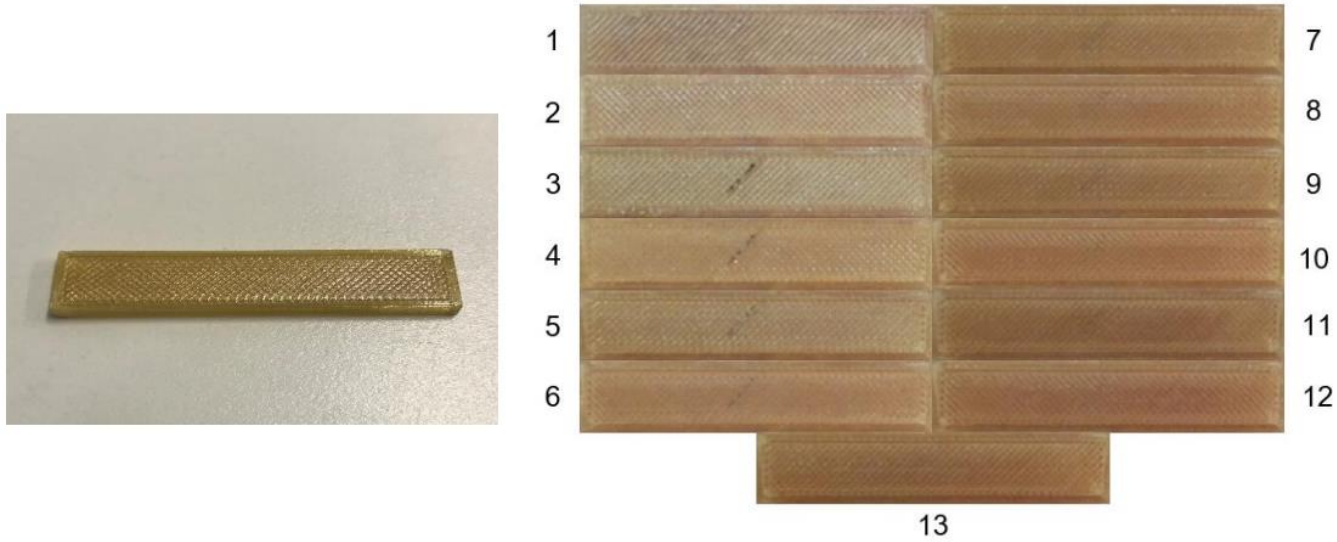


3D Printed heat-sink application.

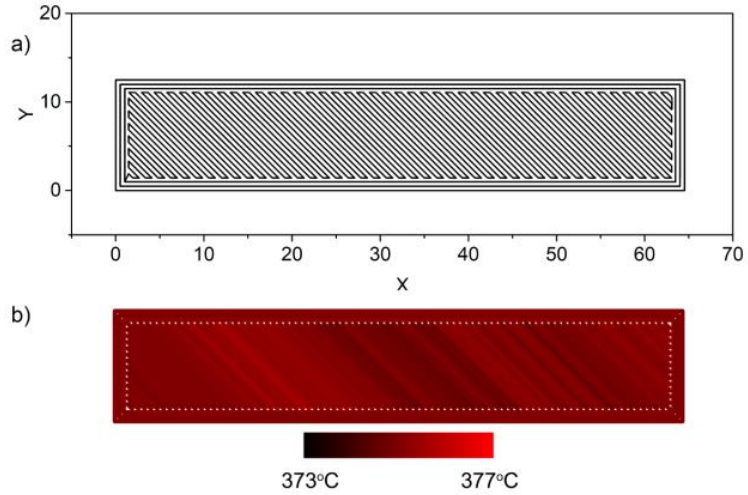
Additive Manufacturing:

Machine Learning Studies

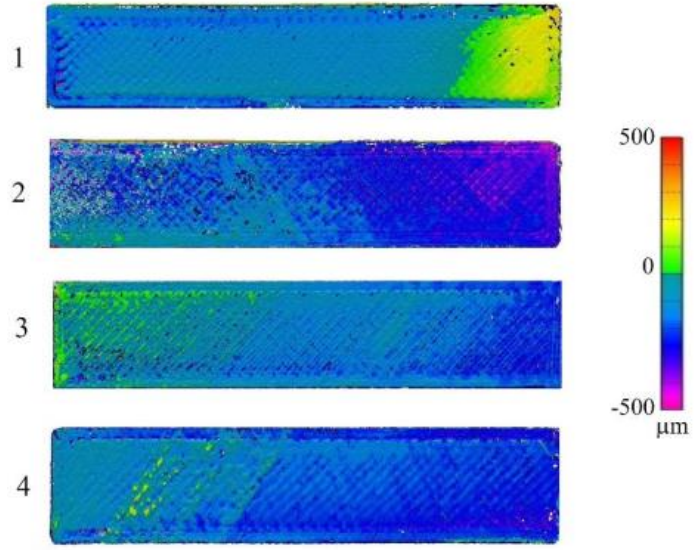




A DMA test sample printed with a 3D printer and images of 13 different layers of the corresponding sample taken during printing.



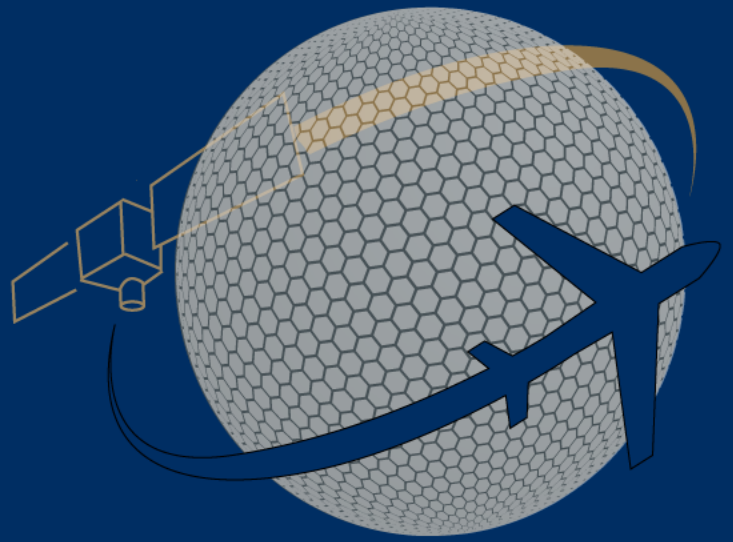
(a) Printing paths of a 2D layer of a test sample, and (b) layer picture drawn as a result of matching these paths using sensor data of nozzle temperature.



Surface topologies of four different samples obtained by laser measurement probes.

Facilities

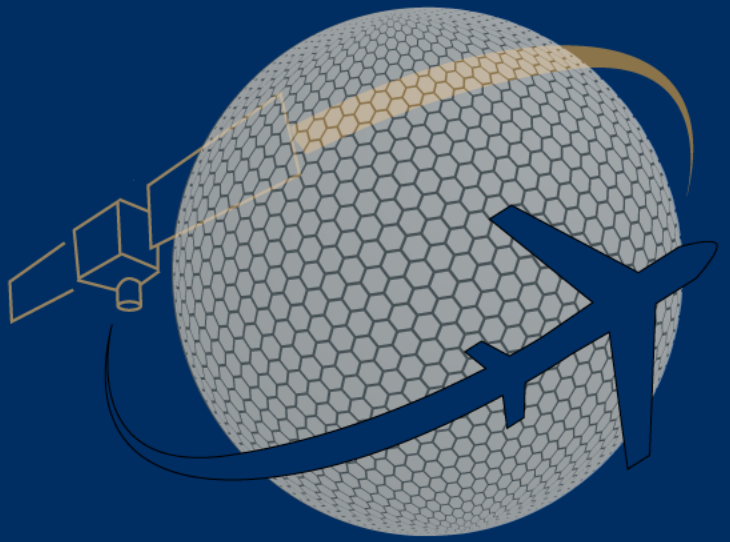
Nanomaterial Synthesis Laboratory

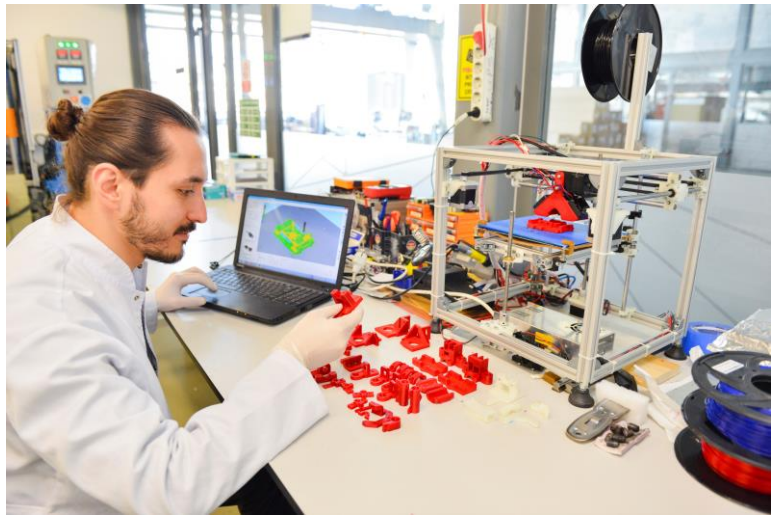


Synthesis and optimization of various nanomaterials (e.g C-based and BN-based nanostructures) has been conducted in nanomaterial synthesis laboratory. The modified nanomaterials in this laboratory are to provide required nanocomponents such as reinforcements for nanocomposites, catalysts for filtration, fabrication of the micro–nano fluidic devices.

- Chemical Vapor Deposition
- Densificator
- Electrospinning Setup
- Gas Filtration System
- Fume Hood
- High Temperature Furnace

Composite & Additive Manufacturing Laboratory





Our laboratories and facilities are very well equipped with all the components needed to engineer composites from part design and analysis to final production. Our multi-disciplinary team mainly works on laminated and sandwich polymer matrix composite structures using several methods and materials listed below:

- Hand lay-up
- Heatable plate under vacuum
- Vacuum infusion
- Autoclave
- Hot press
- 3D printers

Chemical Process Laboratory

Now with support of faculty laboratories, we are able to serve polymer synthesis, electrospinning, electrospraying, and polymer film coating. We are fully equipped with the required facilities for fabrication of advanced technology materials. The instruments in the chemistry lab are listed as:

- Magnetic stirrers
- Analytical balances
- Horn sonicator
- Homogenizator
- Spin coating
- Dip coating

Advanced Characterization Laboratory

- TA-DMA 850, Dynamic Mechanical Analyzer
- TA-Discovery HR-2, Hybrid Rheometer
- TA-TGA55, Thermogravimetric Analysis
- Shimadzu AGS-X, Universal Testing Machine

Thank you for your attention!

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