Advanced Composites Laboratory (IGRM 1308)

PI: Dr. Jitendra S. Tate

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https://composites.engineering.txst.edu/

Gradaute Researchers:

- Arigbabowo Oluwalsola – PhD in MSEC program
- Rahul Sheley - PhD in MSEC program
- Mandesh Khadka – MS in MME Program
- Kiran Poudel – MS in MME Program
- Pratik Karkhanis – MS in MME Program
- Mohamd Sufian – MS in MME Program
- Esmer Trevino (C-Fan) - MS in MME Program
- Kyle Johnson (TRI Austin) – MS in MME Program

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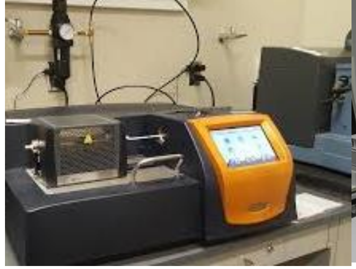


Jitendra S. Tate

Professor, Manufacturing Engineering

Education:

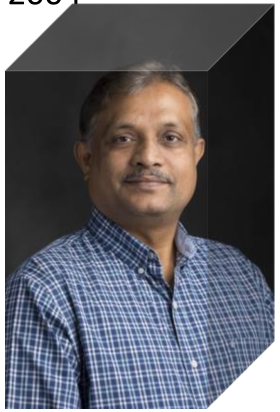
- PhD Mechanical Engineering (Mechanics & Materials), 2004
North Carolina A &T State University
- MS Mechanical Design Engineering, 1996
University of Pune, India
- BS Mechanical Engineering, 1990
University of Pune, India

Awards:

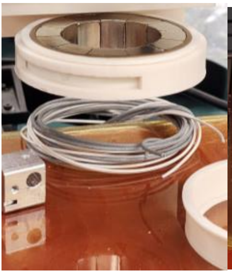
- Composite Educator of the Year: 2009 and 2020
Society of Plastics Engineering
- Presidential Award for Excellence in Teaching: 2018
Texas State University
- Presidential Award for Excellence in Service: 2020
Texas State University

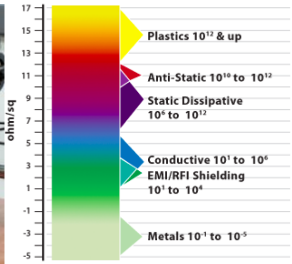
Weblinks:

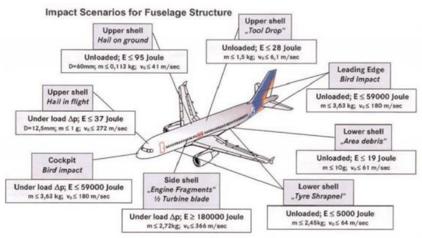
- Faculty Profile: https://faculty.txstate.edu/profile/1922481
- Advanced Composites Lab: http://composites.engineering.txstate.edu

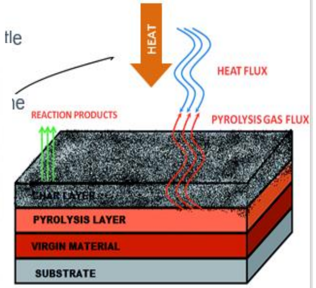


- ❑ Development, manufacturing, and characterization of high-performance thermoset and thermoplastics polymeric matrix composites for industrial, aerospace, sports, biomedical, and energy applications such as,
  - ❑ Thermal Protection Systems-TPS e.g. rocket ablatives,
  - ❑ Fire-retardant interior structures of mass transit and aircraft,
  - ❑ Lighter and damage-tolerant wind turbine blades,
  - ❑ Conductive/magnetic/high temperature composites for 3D printing,
  - ❑ Bio-based composites using natural fibers (kenaf, ragweed, hemp, agricultural waste)
- ❑ Characterization and progressive failure analysis of polymers, elastomers, and composites under mechanical loading (static, fatigue, and impact); thermal loading; FST (fire, smoke and toxicity); and ablation
- ❑ Fatigue of composites – Life prediction modeling and damage mechanisms
- ❑ Low velocity and ballistic impact on composites
- ❑ Environmental, health and safety aspects of nanotechnology safety









Research

- Development, manufacturing, and characterization of high-performance thermoset and thermoplastics polymeric matrix composites for industrial, aerospace, sports, biomedical, and energy applications such as,
  - Thermal Protection Systems-TPS e.g. rocket ablatives,
  - Fire-retardant interior structures of mass transit and aircraft,
  - Lighter and damage-tolerant wind turbine blades,
  - Conductive/magnetic/high-temperature composites for 3D printing,
  - Bio-based composites using natural fibers (kenaf, ragweed, hemp, agricultural waste)
- Characterization and progressive failure analysis of polymers, elastomers, and composites under mechanical loading (static, fatigue, and impact); thermal loading; FST (fire, smoke and toxicity); and ablation
- Fatigue of composites – Life prediction modeling and damage mechanisms
- Low velocity and ballistic impact on composites – damage mechanism
- **Low-cost Manufacturing** of polymeric composites
- Evaluation of Dispersion of Nanoparticles in Thermoset and Thermoplastics
- Environmental, health and safety aspects of nanotechnology safety

Research Capabilities

- Mechanical characterization of composites
    - Static; Fatigue, Low Velocity Impact loading, and Ballistic Impact Loading
    - Fatigue life prediction modeling
    - Damage mechanisms in composites under Impact Loading
- Thermal characterization of nanoparticle-modified polymers
    - Thermogravimetric analysis (TGA) to determine the effect of nanoparticles on the thermal stability of polymers
    - Differential Scanning Calorimetry (DSC) to determine the effect of nanoparticles on the crystallinity of polymers
    - Thermo Mechanical Analyzer (TMA) to the evaluate linear coefficient of thermal expansion
- Microscopy Characterization of nanocomposites with support from ARSC
    - Optical microscopy studies to determine the extent of damage.
    - Transmission electron microscopy (TEM) to evaluate dispersion state.
    - Scanning electron microscopy (SEM) to evaluate the damage after testing.
- **Nondestructive testing of composites after testing**
    - Infrared thermography

Materials

- **Reinforcements:** Carbon (PAN and Rayon based), E-glass, Silica, Hemp, Ragweed, and Coconut Coir
- **Thermosets:** Polyester, Vinyl ester, Epoxy, Cyanate ester, Polyurethane, Polysiloxanes, Phenolic (water and IPA based)
- **Thermoplastics:** PA 6, PA 11, PA 12, PA 46, PLA, TPU
- **Nanoobjects:** MWCNT, CNF, ANF, HNT, NGP, Nanosilica
- **Micron size particles:** Strontium Ferrite, Core Rubber Shell

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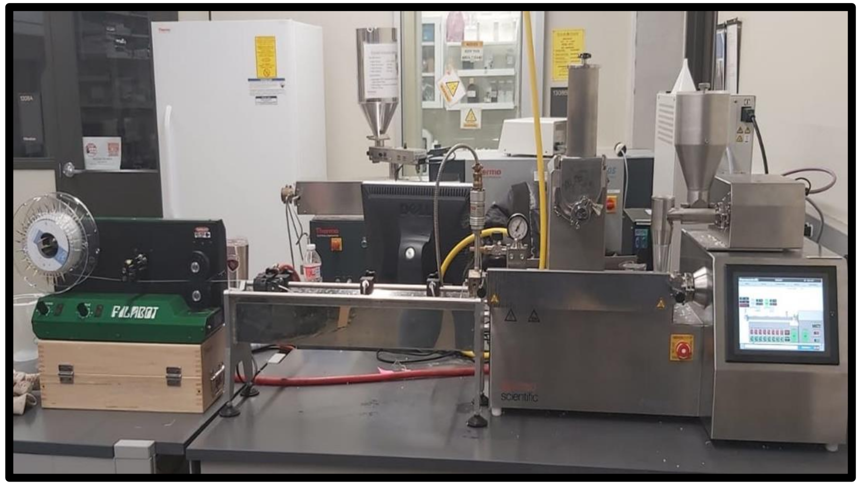
Equipment

Dispersion equipment for nanoparticle into thermoset and thermoplastic polymers

ULTRASONICATOR

THREE ROLL MILL (CALENDARING APPROACH)



COROTATING TWIN SCREW EXTRUDER

HIGH SHEAR MIXER

CENTRIFUGAL
PLANETARY MIXER

SINGLE SCREW EXTRUDER

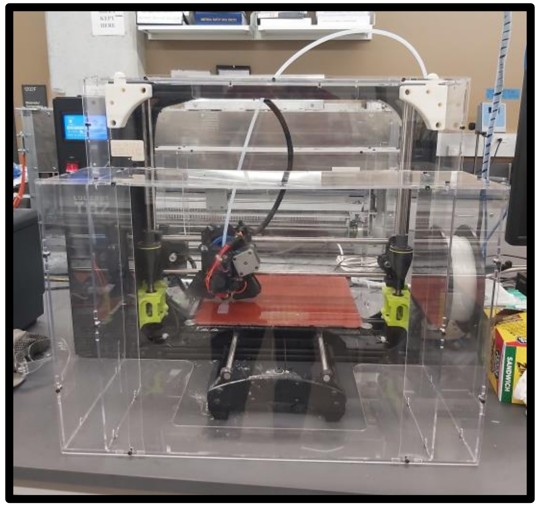
DISPERSION TECHNIQUES…

Selection of suitable dispersion technique enables maintaining nanofiller characteristics and yields desired results

	Ultrasonication		Stand Mixer	Planetary Centrifugal Mixer	High Shear Mixer	Three Roll Mill
	Bath Type	**Horn Type**				
Energy Imparted	low	High	Low	Low to Moderate	High	High
Fracture	Low	High	Low	Low	High	Low
Debundling	Low	High	Low	Low to moderate	High	High
Air bubble entrainment	Low	High	High	Low	High	Moderate
Scale-up	Not feasible	Not feasible	Not feasible	Not feasible	Feasible	Feasible

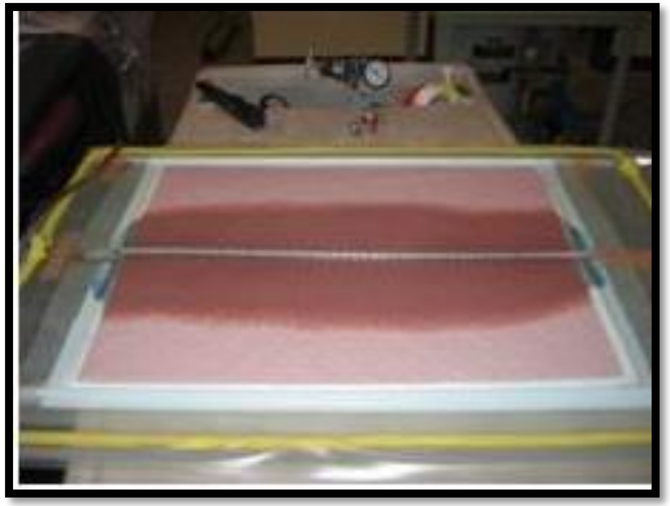
Equipment

Manufacturing equipment for thermoset and thermoplastic nanocomposites



FDM 3D Printer

Injection Molding



Vacuum Assisted Resin Transfer

Compression Press

**Advanced Composites Laboratory is equipped with a specialized nanocontainment room for safe storage and safe handling of nanoparticles

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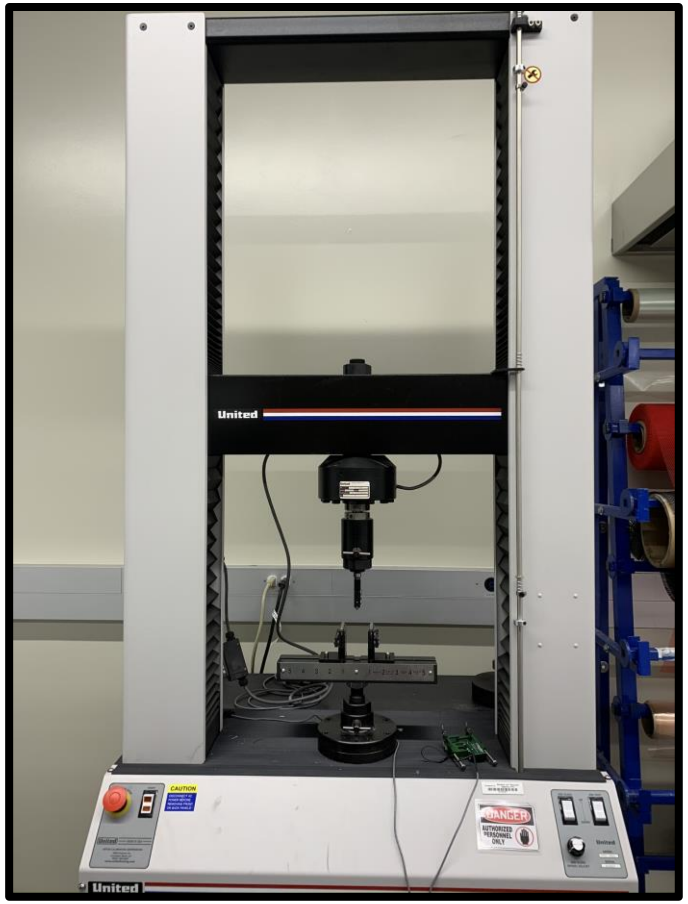
Equipment

Mechanical characterization equipment for thermoset and thermoplastic nanocomposites

MTS SERVO HYDRAULIC TESTING EQUIPMENT
Max Load: 100kN

LOW VELOCITY DROP TOWER IMPACT TESTER
Max. Energy: 405J



UTS ELECTRO-MECHANICAL TESTING EQUIPMENT
Max Load: 50 kN

MTS EXCEED E45
Max Load: 1kN – 10kN

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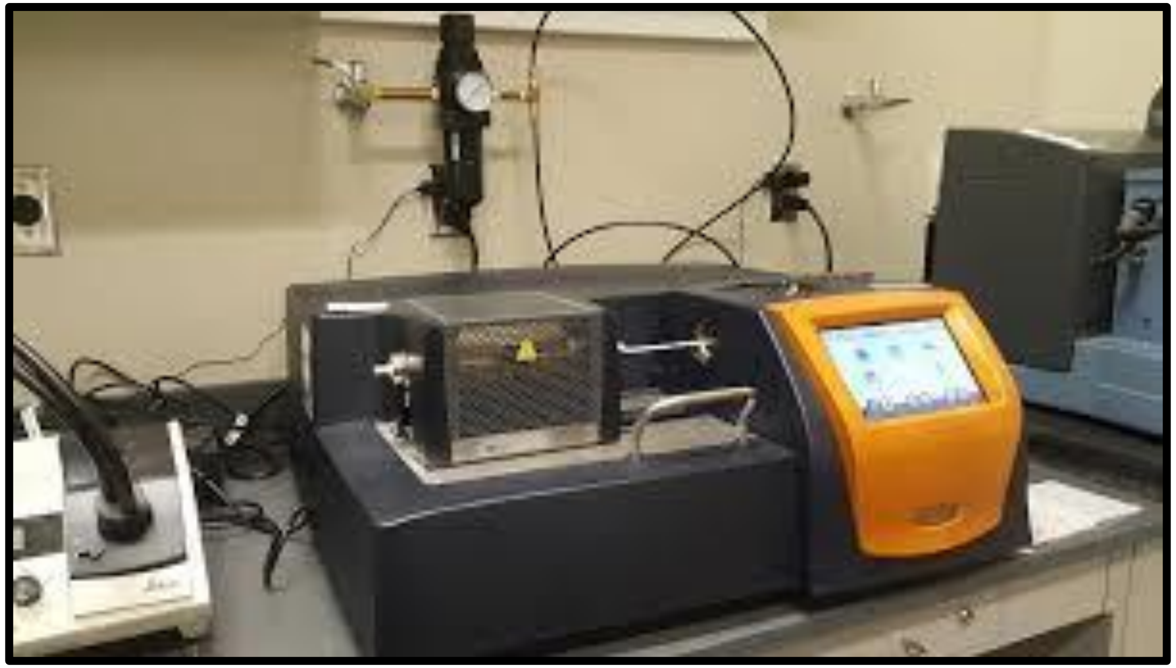
Equipment

Thermal characterization equipment for thermoset and thermoplastic nanocomposites



DISCOVERY 650 SIMULTANEOUS DSC TGA

Max. Temperature: 1500 C

TMA Q400

Temp. Range: -150C to 1000C

Force Range: 0.001 to 2N

Application Oriented Innovative Composites Materials Development

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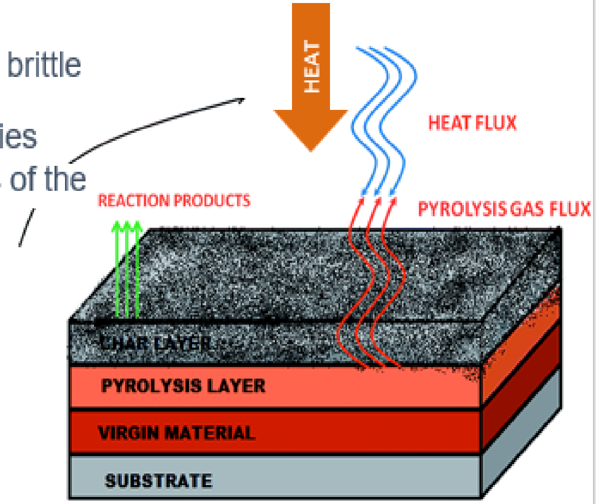
Ablative composites for aerospace applications

Ablation

Protective material that predictably degrades over time

1. Char layer limits oxygen diffusion
2. Polymer char is weak and brittle
3. Better mechanical properties increase the effectiveness of the char layer



Advanced TPS Material

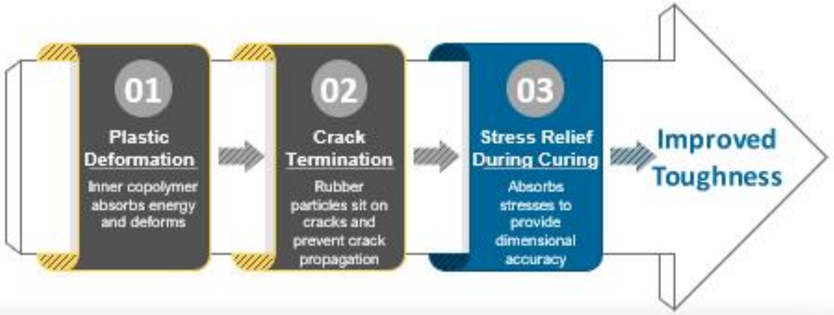
Architecture
Compression molding, 2D, 2.5D, 3D

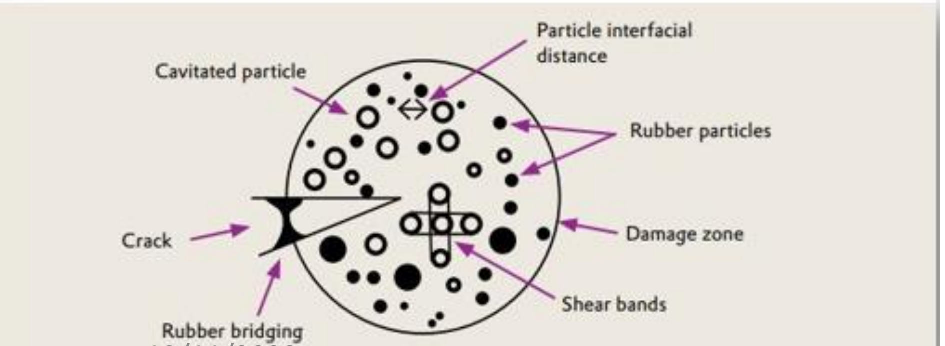
Matrix
Epoxy, phenolic, cyanate ester, polysiloxane

Reinforcement
Carbon, silica, glass

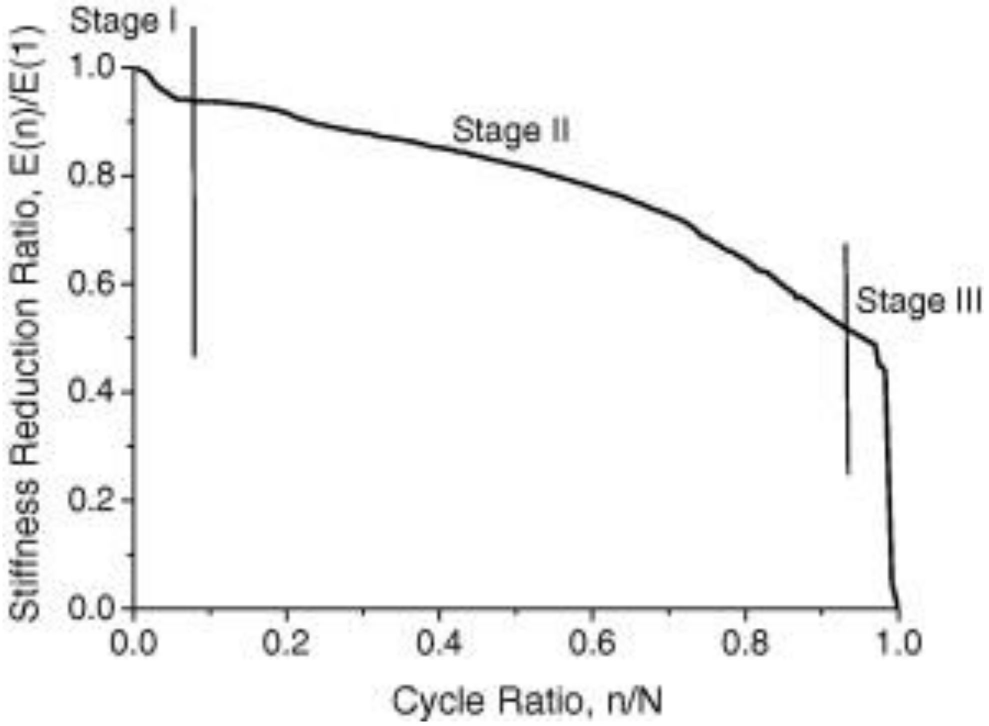
Fillers
Multiwall carbon nanotubes, nanoclay, graphite

Fatigue Resistant Composites

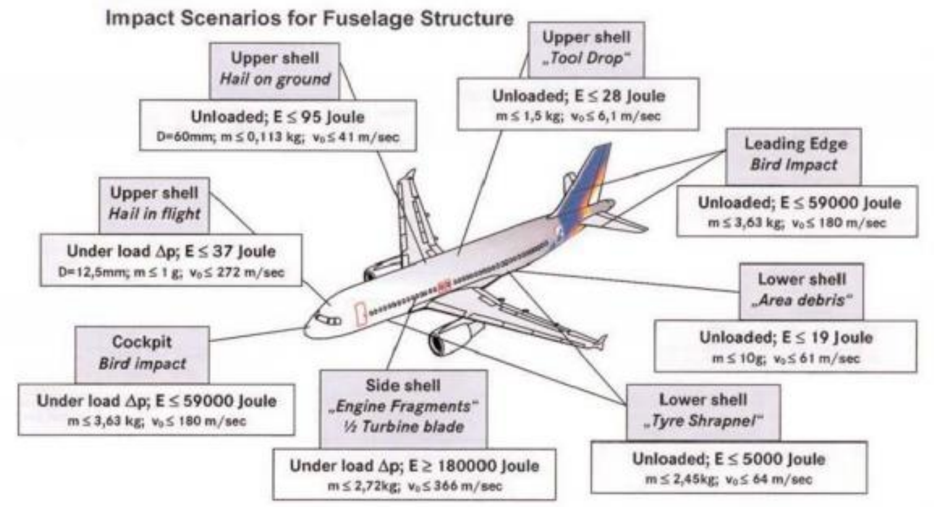




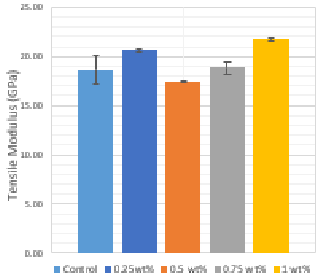
- Composites are subjected to constant cyclic loads.
- Addition of CSRP, CTBN micro-nano fillers to enhance fatigue life.
- Development of stiffness degradation model which can predict the life of composites under fatigue loading.

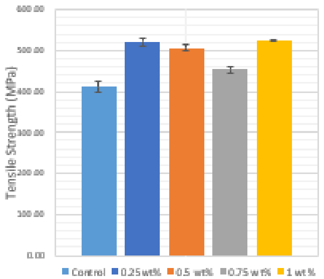


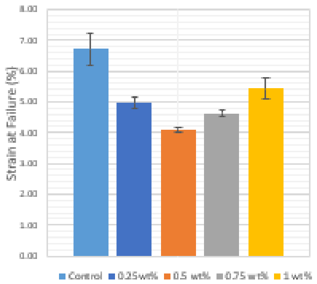
Impact Damage Resistant Composites

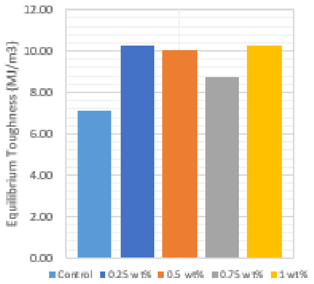


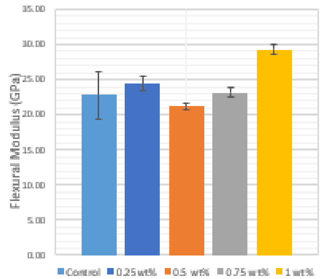
- Impact damage can be due to debris, hail, projectile hits etc.
- Addition of alumina nanofibers to further enhance damage absorption.
- Development of a predictive model to estimate maximum energy absorption from static tests.

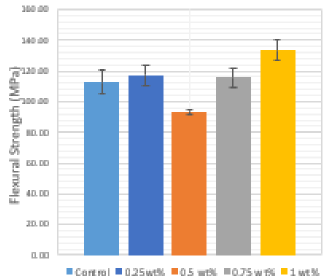


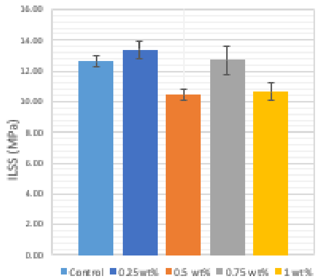




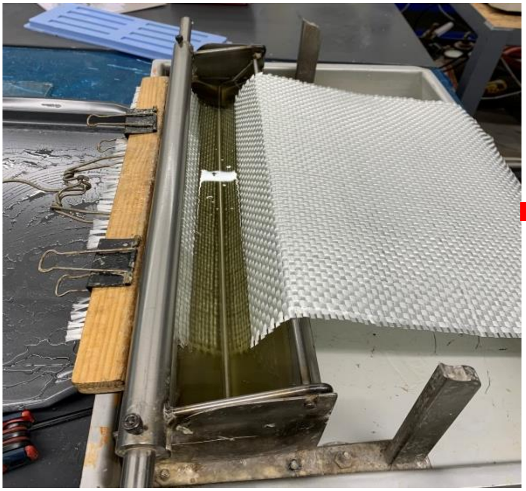








MANUFACTURING…



Double drip resin bath containing resin

E-Glass fabric being pulled through the resin bath

Wabash Hydraulic Compression Press

14 in

14 in

Number of layers :

6 layers for static tests

14 layers for LVI and Ballistic Impact.

Area of laminate:

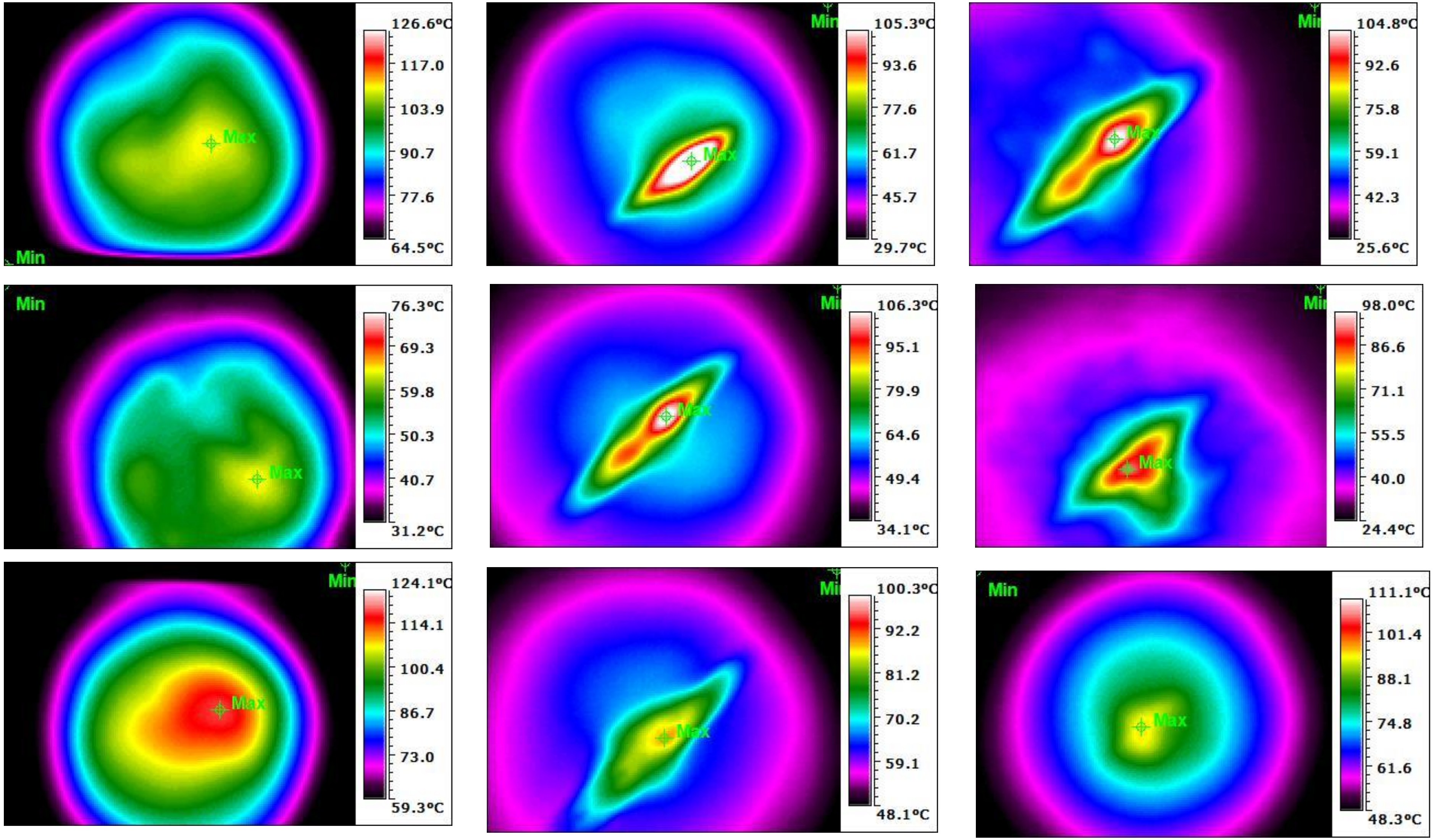
14in x 14 in

Thermal Imaging Results

Impact from height 914 mm

Impact from height 711 mm

Impact from height 508 mm



Nano- Almina modified glass fiber epoxy nanocomposite

Nano- Silica modified glass fiber epoxy nanocomposite

Un-modified glass fiber epoxy nanocomposite

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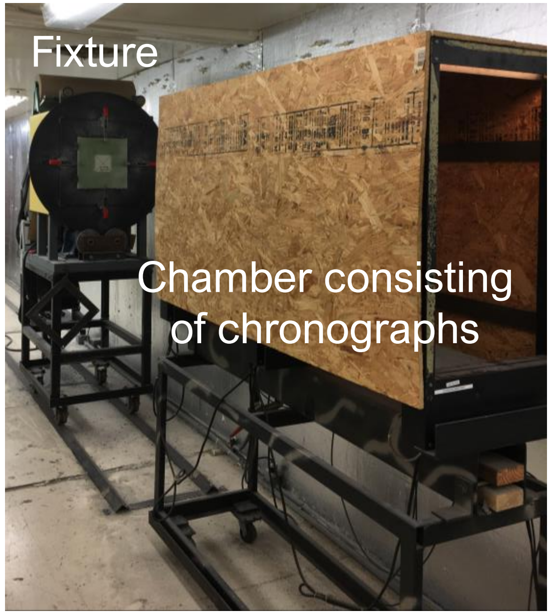
BALLISTIC IMPACT

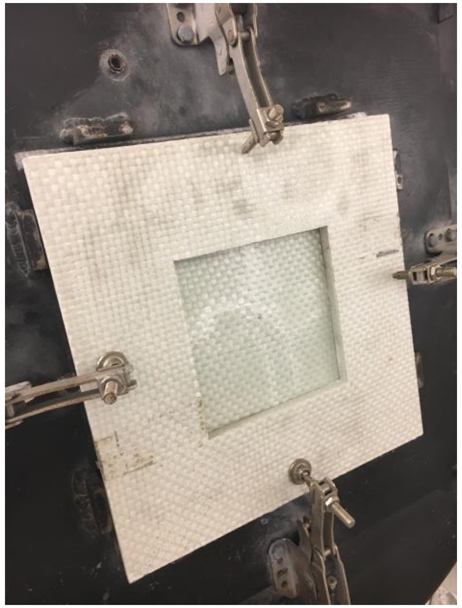
Qualification of developed composite against ballistic velocity threat of UL-752, Level 1 and Level 6

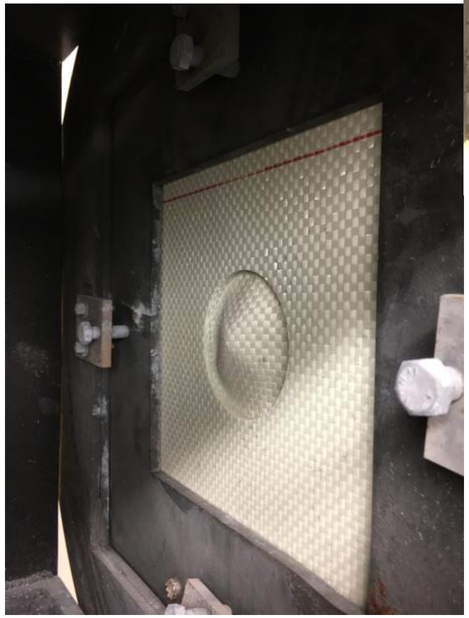
Rating	Ammunition	Weight (in grains)	Velocity range (min – max m/s)
Level 1	**9 mm FMJ with lead core**	**124**	**358 m/s – 394 m/s**
Level 2	.357 Magnum JSP	158	381 m/s – 419 m/s
Level 3	0.44 Magnum SWGC	240	411 m/s – 452 m/s
Level 4	0.30 Caliber rifle LCSP	180	774 m/s – 851 m/s
Level 5	7.62 mm rifle	150	838 m/s – 922 m/s
Level 6	**9 mm FMJ with lead core**	**124**	**426 m/s – 469 m/s**
Level 7	5.56 mm rifle FMJ military ball	55	938 m/s – 1031 m/s
Level 8	7.62 mm rifle FMJ military ball	150	838 m/s- 922 m/s

Ballistic Impact Testing...

Property	Sample Dimensions	Control	UT-Composite	VT-Composite
Ballistic Impact	6in x 4in x ‘t’ 152.4mm x 101.6 mm x ‘t’	4	16	16





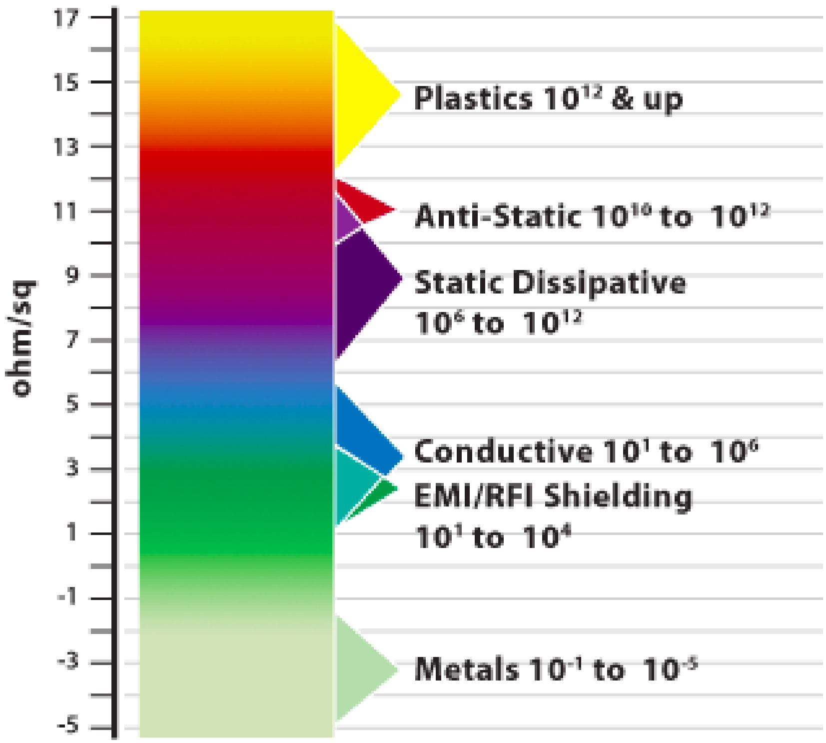


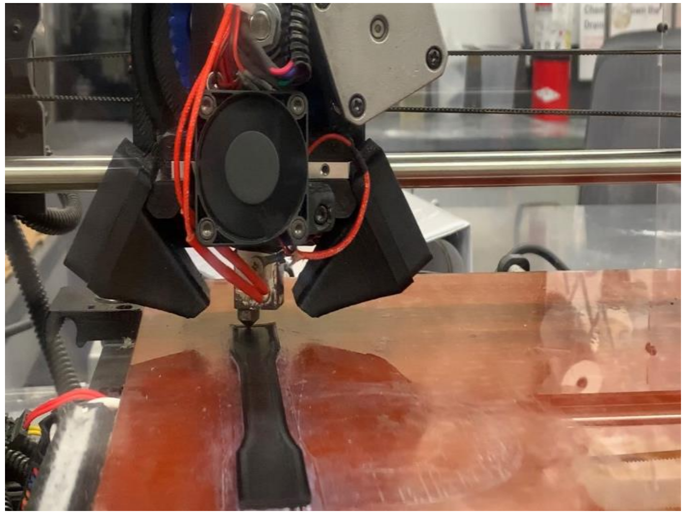
Thermoplastic nanocomposites for ESD application which are 3D printable

- ESD is of major concern in aerospace, automotive, oil and gas, electronics industry to name a few. Estimated $40 billion losses due to ESD damage in electronics industry alone.

- Use of conductive nanofillers such as NGP, CNF, CNT to increase conductivity without sacrificing the mechanical properties.

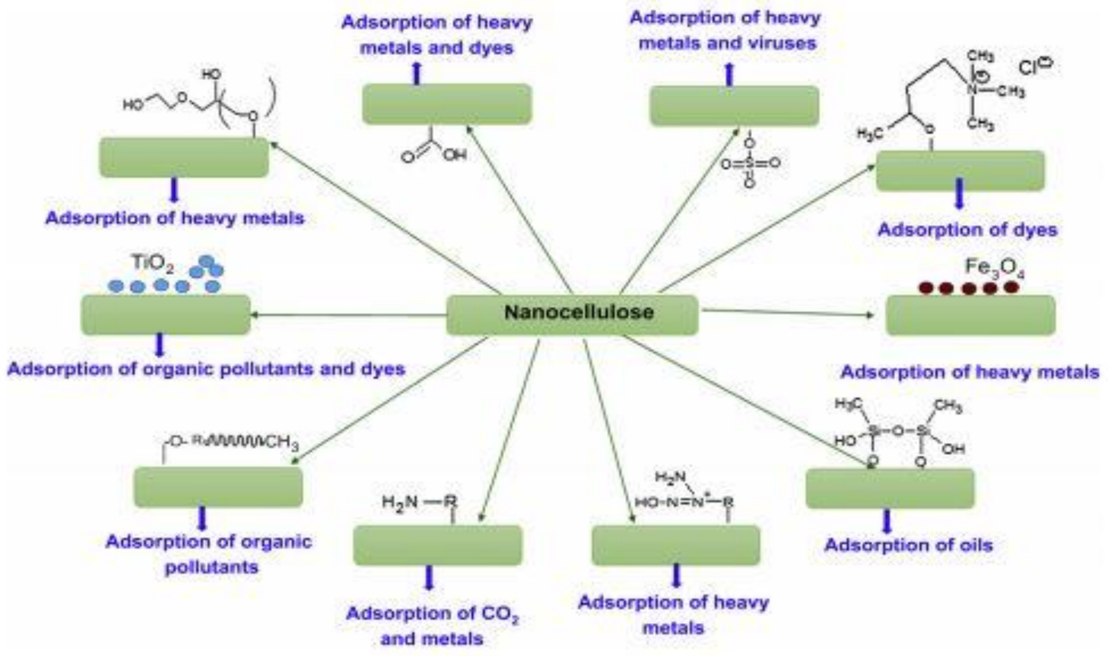
- Thermoplastics possessing excellent multifunctional properties with potential application in these applications include: PA6, PA11, PA12, PA645, PA66, PLA, PETG etc.

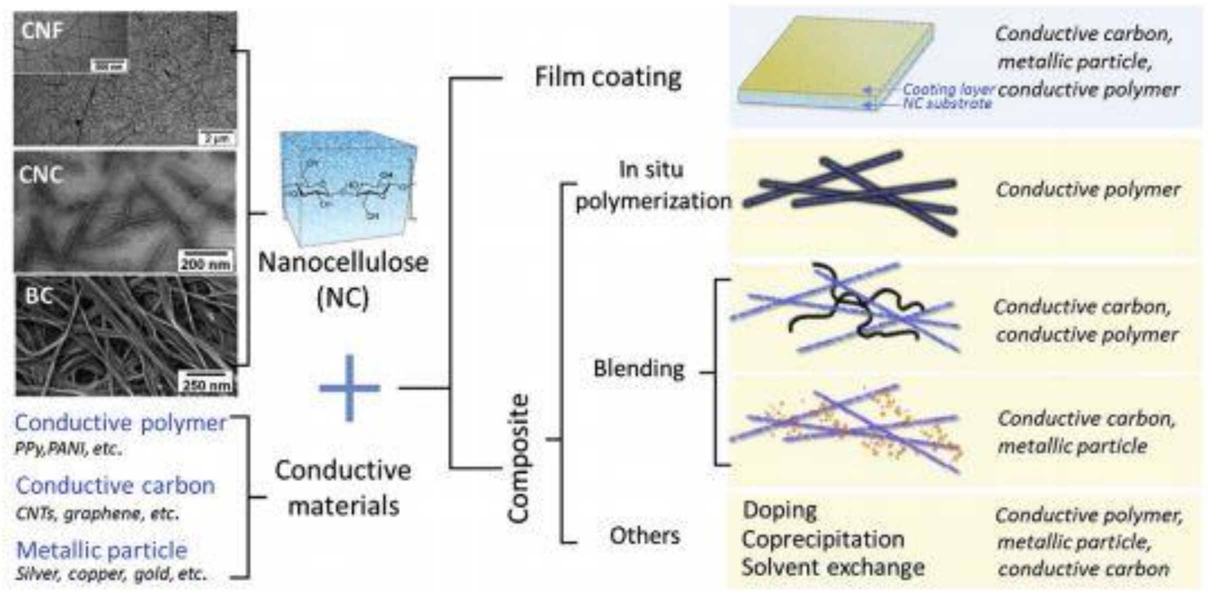




SUSTAINABLE FIBERS DERIVED FROM CELLULOSE FOR USE IN POLYMER COMPOSITE MATERIALS

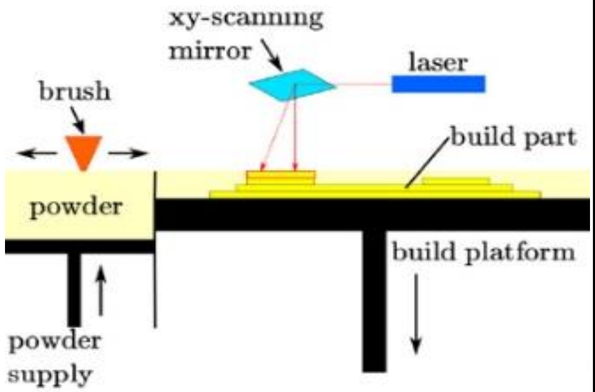
- Cellulosic materials with responsible research, development and thoughtful deployment can become the choice for sustainable materials.
- Cellulose nanomaterials are widely useful in automotive, medical, cosmetics, electronics etc., in the form of nanocrystals or nanofibers.
- The key critical pathway for progressing research is to apply the benefits of nanotechnology and manufacturing technologies to exploit the unique features for superior and controllable composite performance.





Development of Thermoplastics and Thermosets Composites for Additive Manufacturing

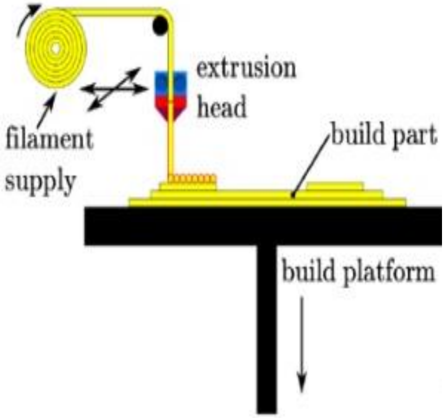
Stereolithography-SLA



Thermoset Polymers to match CTE of Nickel

- **Twin Screw Extruder**
- **Single Screw Extruder**
- **FFF Printers**
- **Compression Molding**
- **Injection Molding**
- **Thermal and Mechanical Characterization**

Fused Filament Fabrication-FFF



FFF Converted to Paste Printer/High Temp Printer

Magnetic Devices
- Matrix: Polyamide 12
- Fillers: Strontium Ferrite-$SrFe_{12}O_{19}$, Neodymium Iron Boron- NdFeB

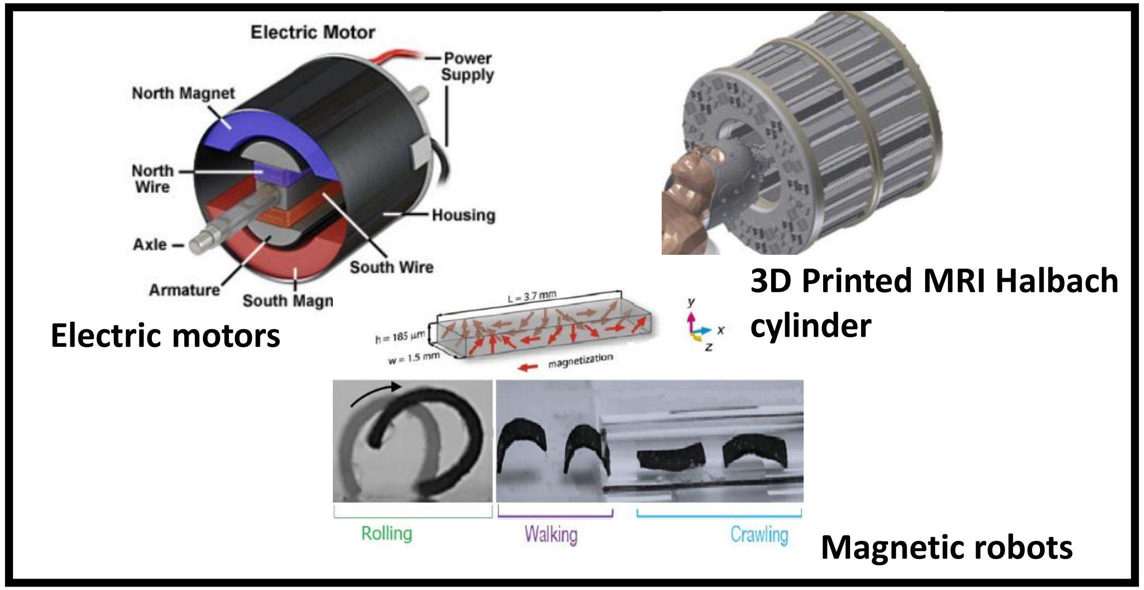
ESD Applications
- Matrix: Polyamide 6, 11, and 12
- Fillers: MWCNT, Carbon Nanofibers-CNF, Nanographene Platelets-NGP

Natural Composites
- Matrix: PLA
- Fillers: Ragweed fibers

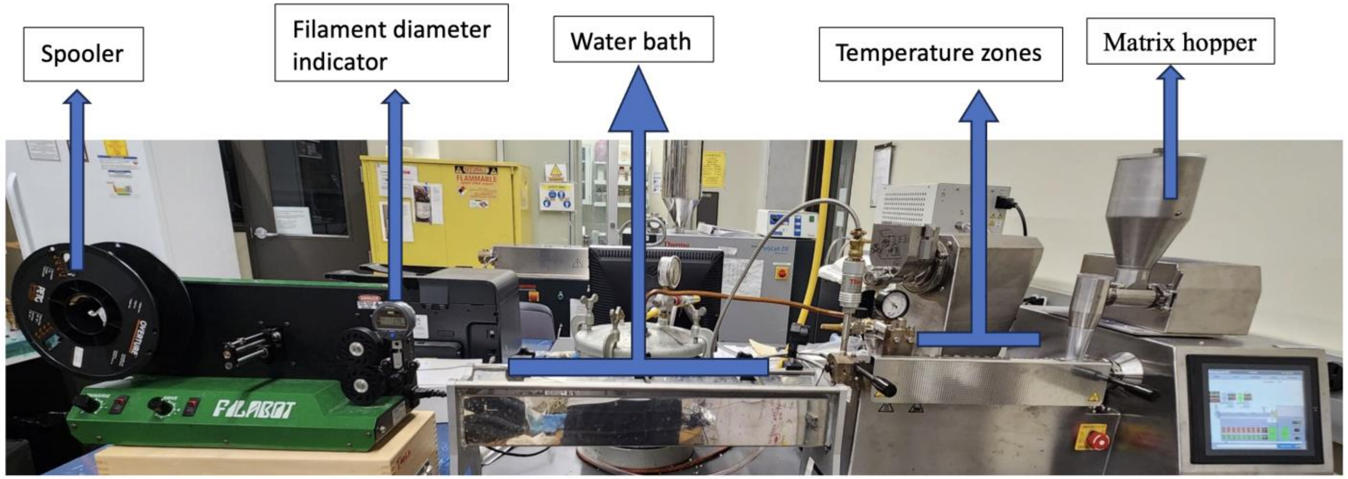
Redesigning of Open-Source FFF Printers
- High Temperature Thermoplastics: PEEK, PEKK, PEI
- Magnetic Field Assisted Additive Manufacturing (MFAAM)
- Paste Printers for High-Temperature Thermoset for Thermal Protection Systems

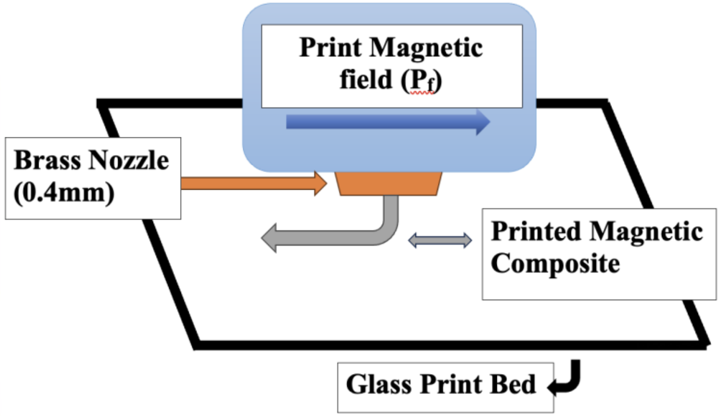
Development of Bonded Magnetic Composite for Magnetic Field Assisted Additive Manufacturing

- **Motivation**
  - More economical than sintered magnets
  - Superior mechanical properties and corrosion resistance
  - Ability to develop intricate and complex 2D and 3D magnetic devices
- **Materials**
  - **Fillers/Reinforcement:** $SrFe_{12}O_{19}$ magnetic powders
  - **Binders/Matrix:** Polyamide 12, Polyamide 4.6 (high-temperature capability)



Potential Applications





Twin Screw Extrusion Technology

Modified Fused Filament Fabrication-FFF

THANK YOU