



From Nano-Reinforced Alloys to Cryogenic Hydrogen Tanks: My Research Journey at AMADE

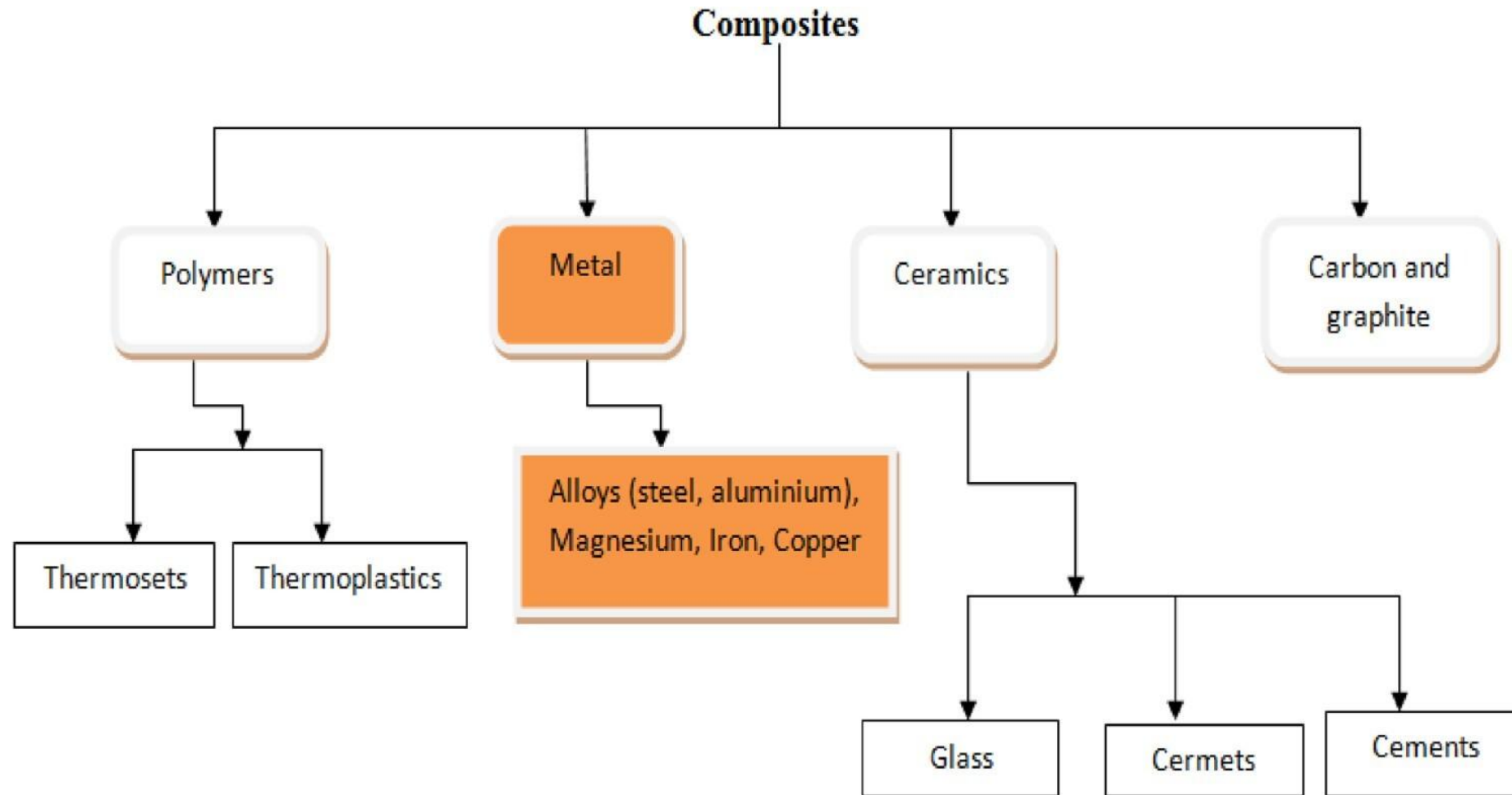
Dr. Nikhil Bharat
Girona, 23/01/2026

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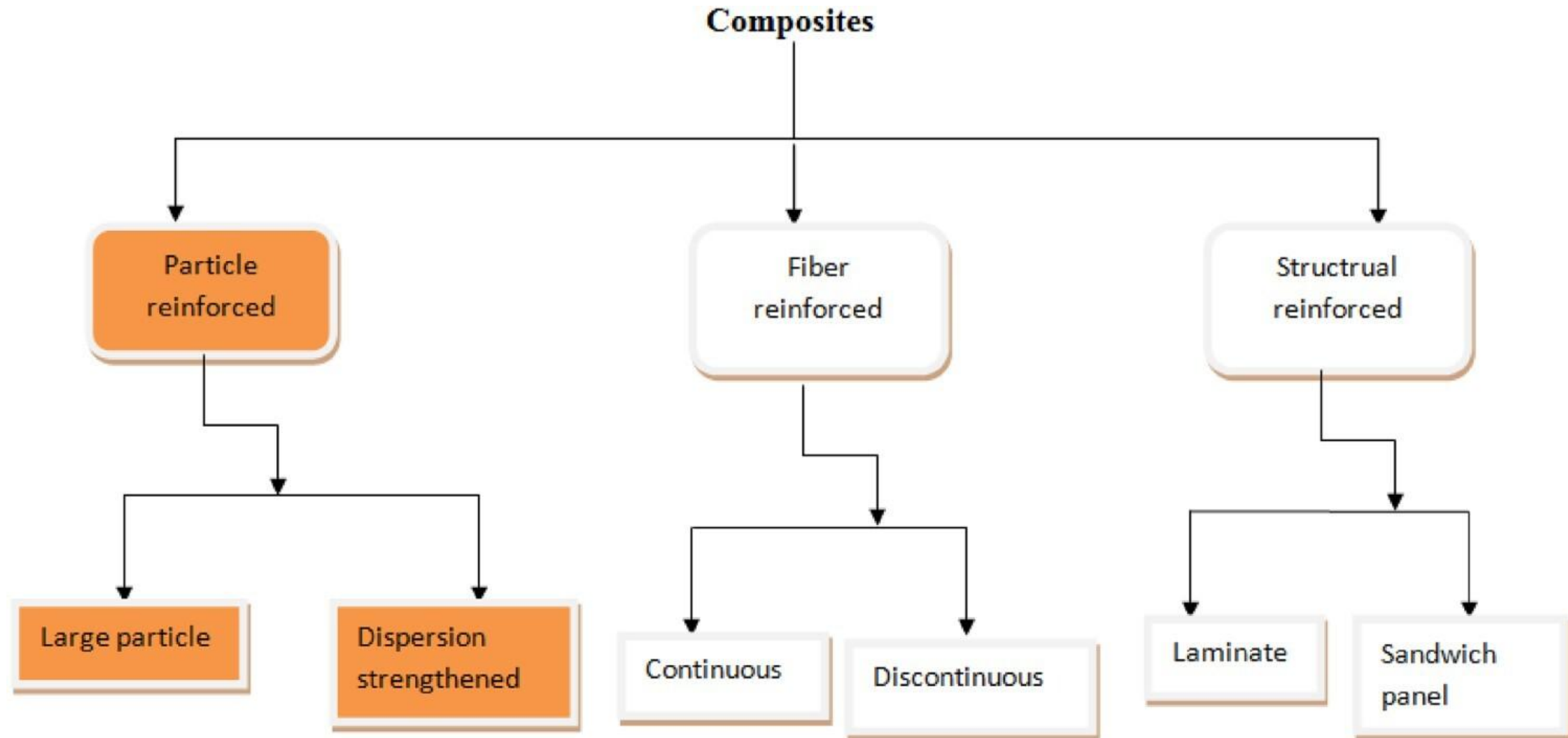
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- **Composites** are those material in which **two phases** are combined together to obtain desired product having better **physical** and **mechanical** properties.



- **Why MMC:** Metal matrix composites combine a **ductile metal** with **hard reinforcements** to achieve higher **strength, better wear resistance**, and improved high-temperature stability than monolithic metals useful for lightweight, high-load engineering components.



Materials selection

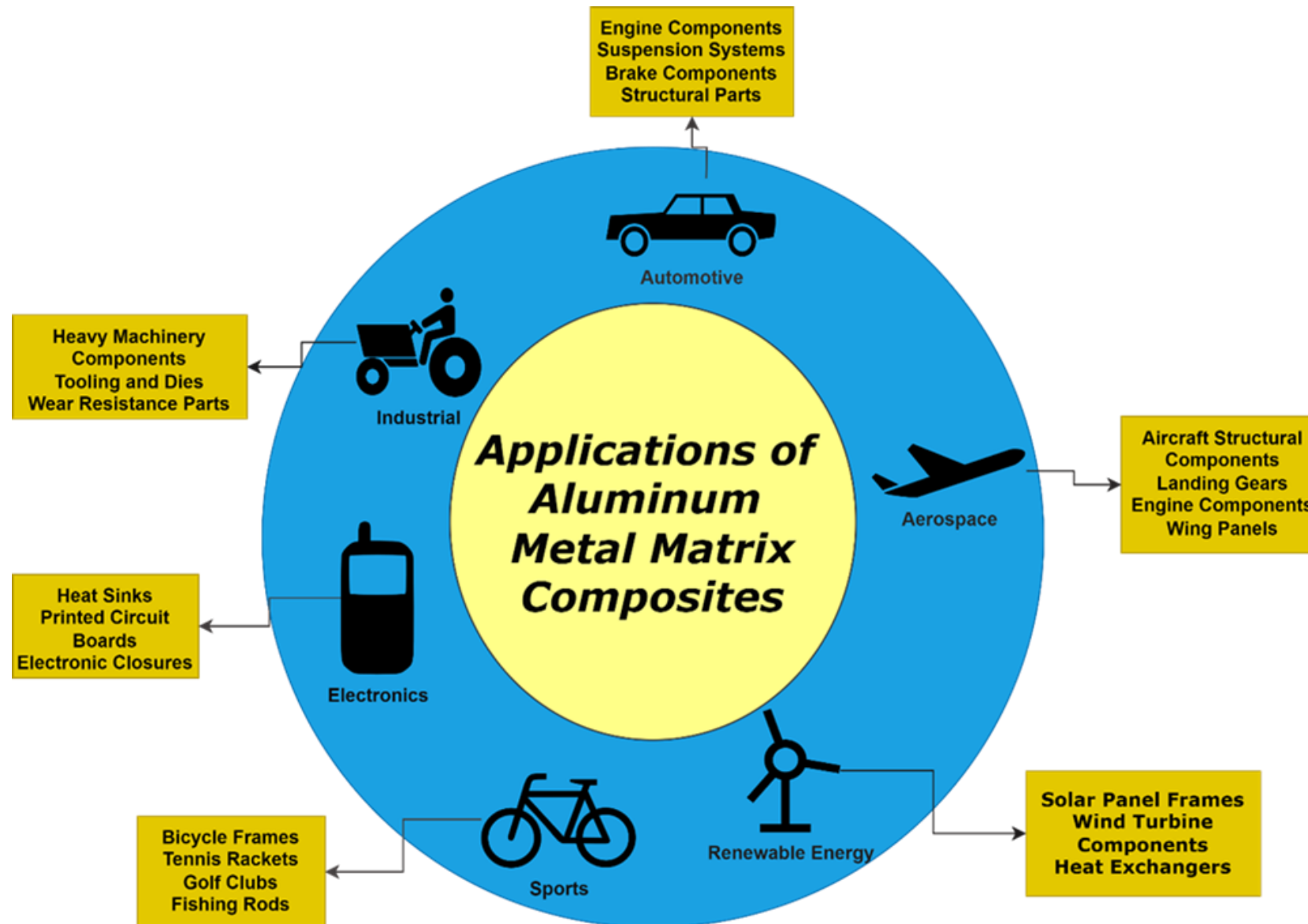
- **AA7178** is a **aluminium** alloy of **7xxx series** .
- AA7178 is a versatile alloy utilized in aviation, architectural as well as transport applications due to its elevated **properties** and **low weight**.
- AA 7178 was used as an advanced version of 7050 by increasing alloying content and used in Boeing 707,737 and DC8 passenger.
- Very few literature is available on Al 7178(2.82g/cm³) matrix alloy.
- **AA7178** finds application in **aerospace industry** and used in the manufacturing **fuselage**, stringers, floor beams, airline passenger seat tracks, **upper and lower wings**.

Zn	Cu	Mn	Mg	Fe	Si	Cr	Ti	Rest
7.1	2.0	0.30	2.7	0.45	0.40	0.26	0.20	Balanced Al

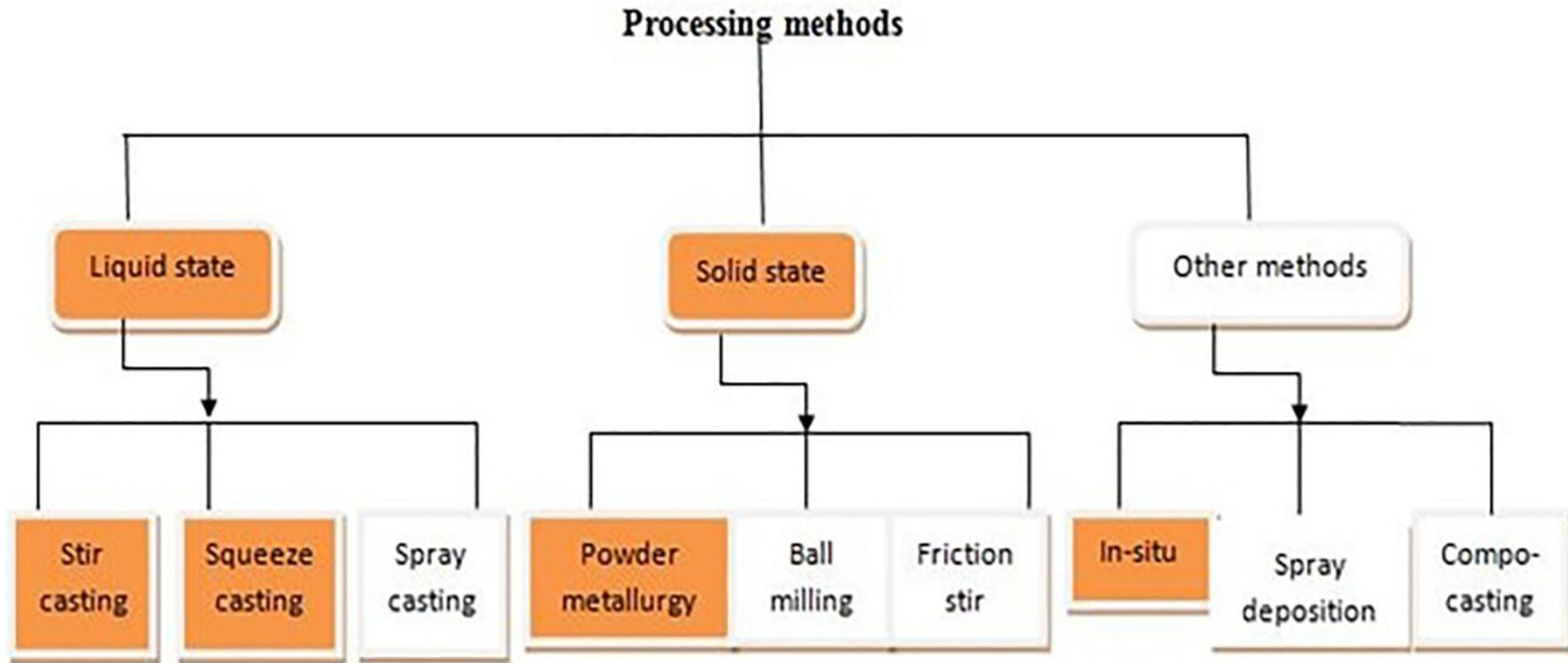
TiO₂ and SiC as reinforcement

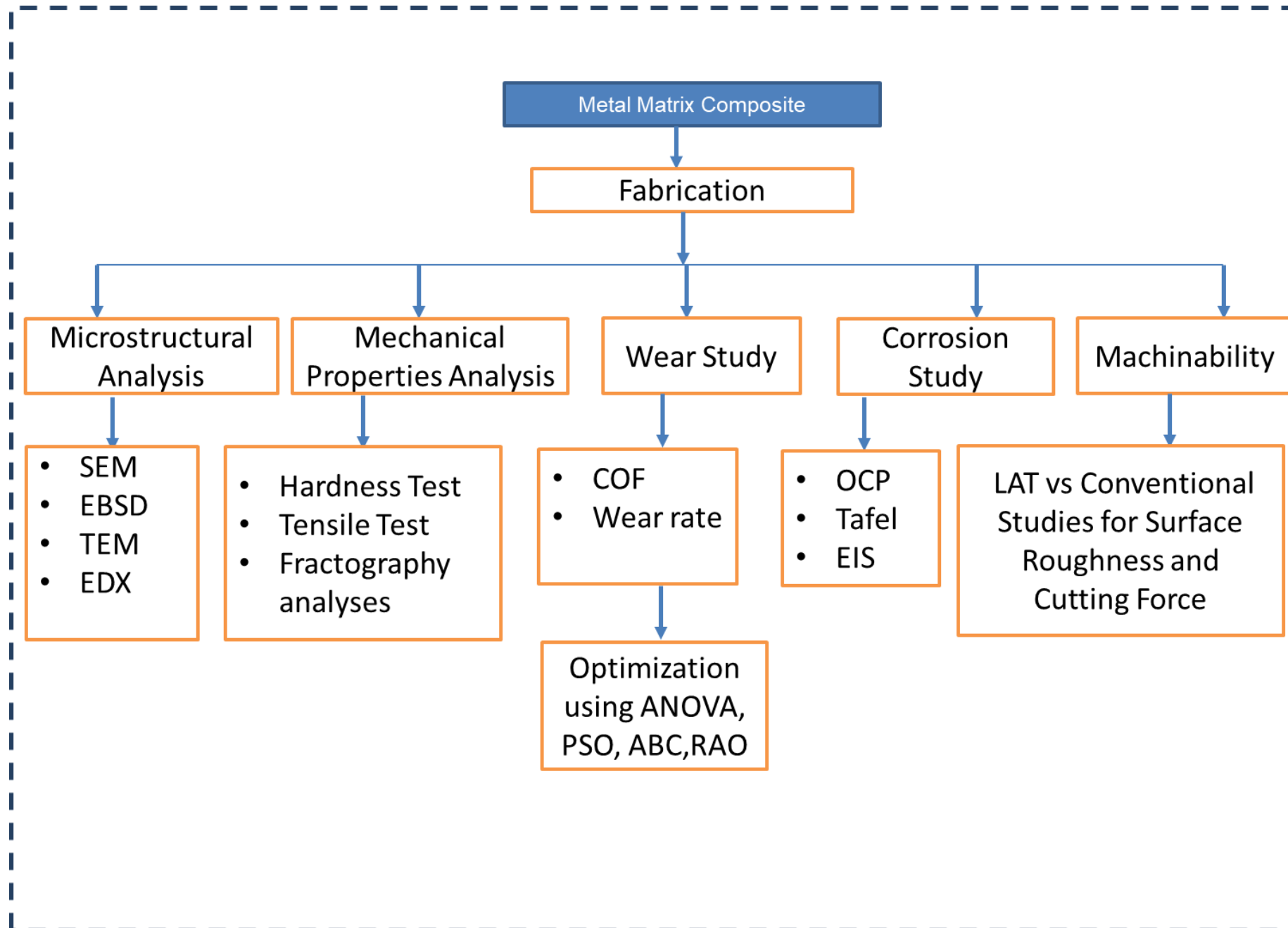
Application	TiO ₂ Nanoparticles	SiC Nanoparticles
Corrosion Resistance	Enhances corrosion resistance in coatings for metals, suitable for marine and chemical industries.	Used in coatings for excellent corrosion resistance, beneficial in chemical processing and marine applications.
Wear Resistance	Improves wear resistance in coatings and materials, applicable in automotive and machinery components.	Reinforces composites for wear-resistant automotive parts like brake pads and clutches.
Automotive Applications	Enhances corrosion resistance , potentially improving durability and performance.	Vital in manufacturing wear-resistant brake pads and clutches, ensuring high durability and performance.

Applications

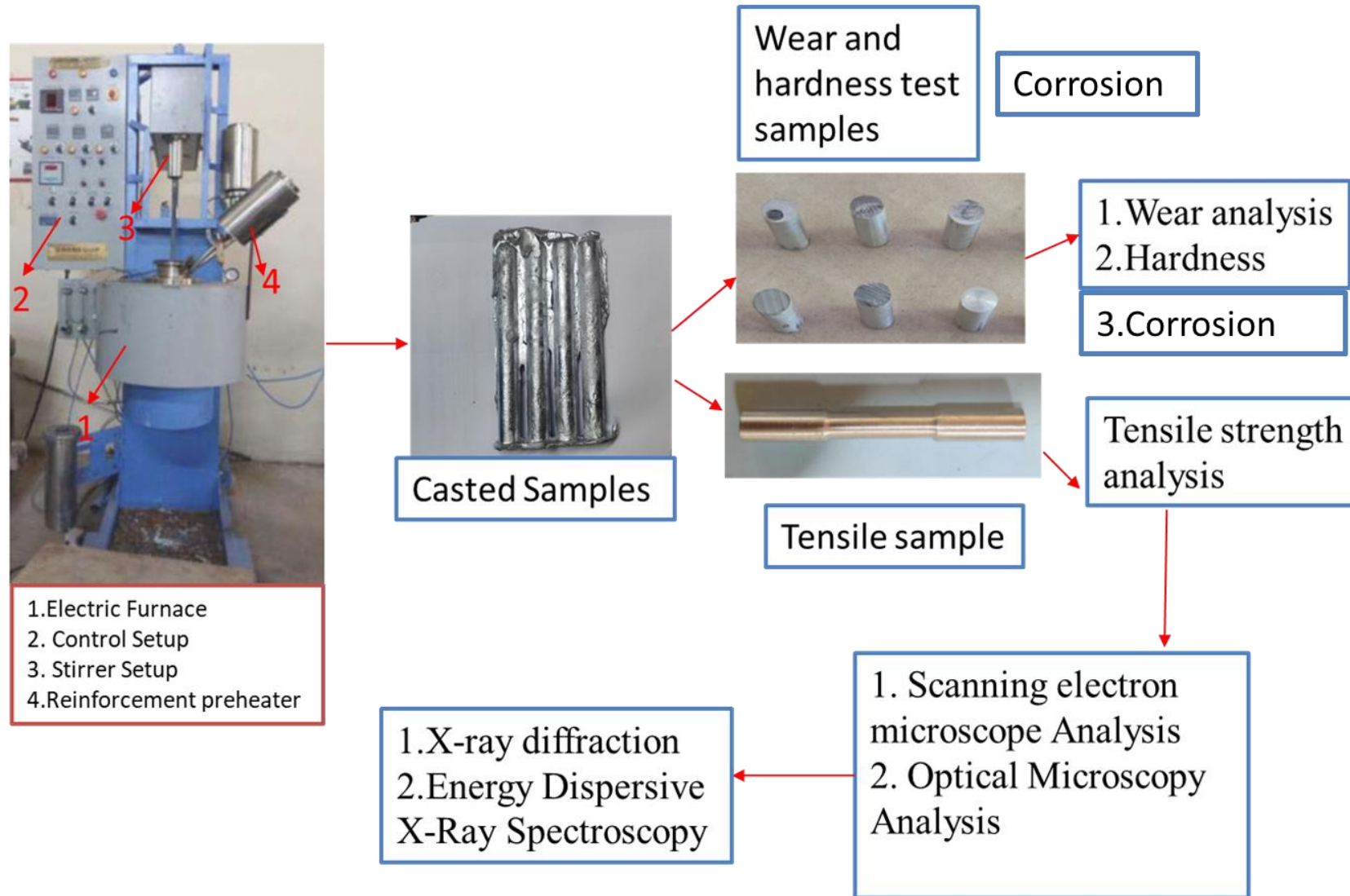


Fabrication Techniques of AMMC

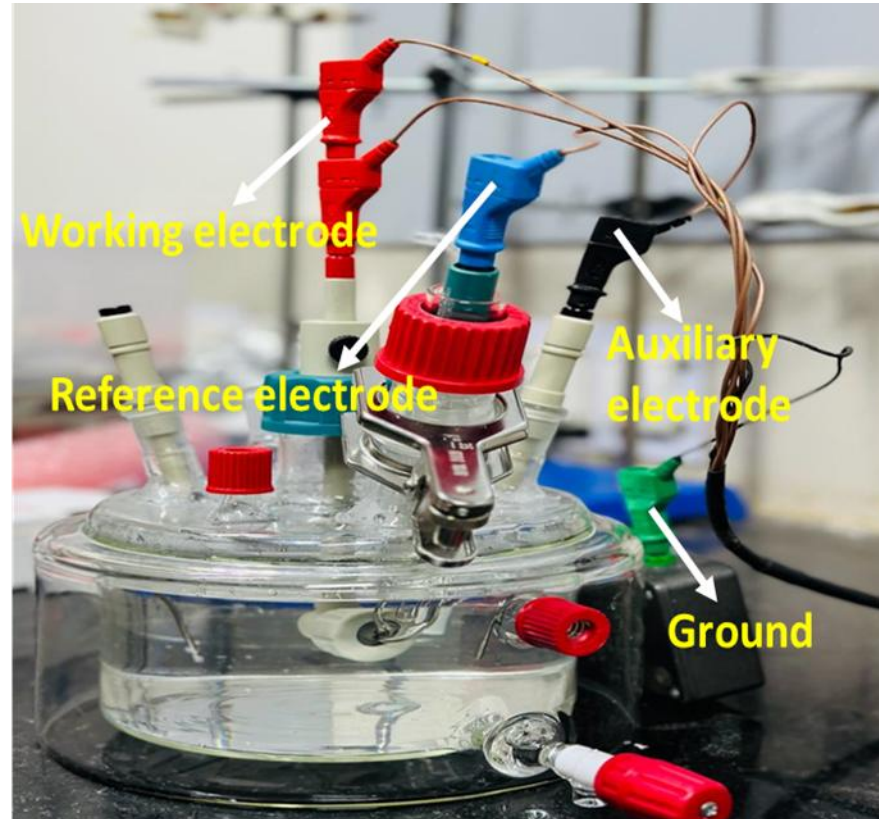




Fabrication and Characterization



Corrosion and Wear Testing



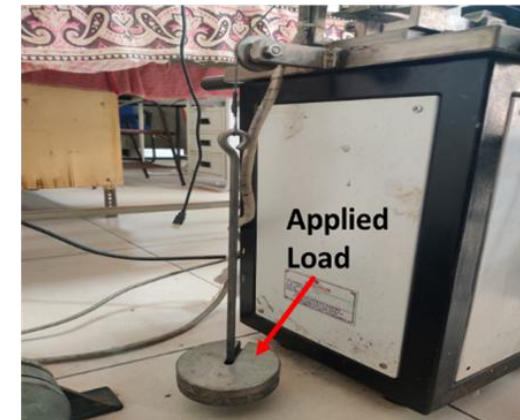
Top View



Front View

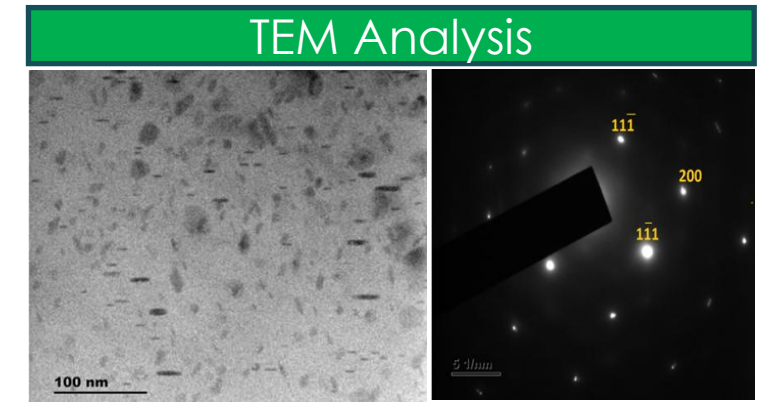
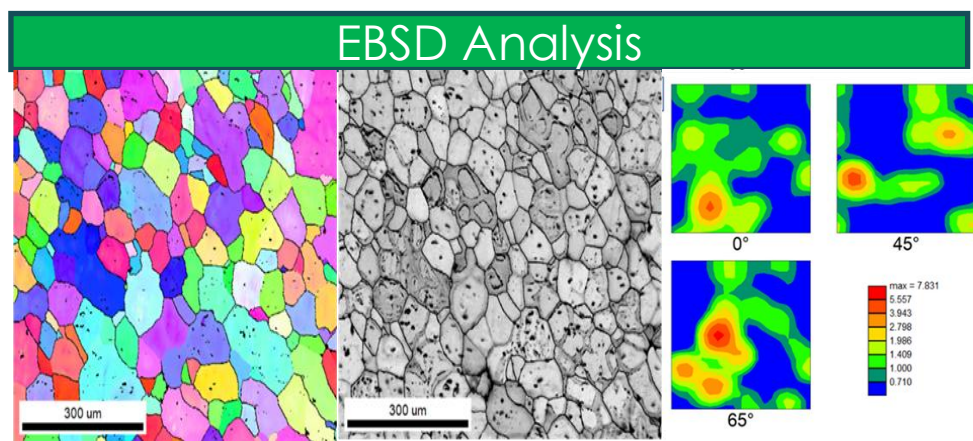
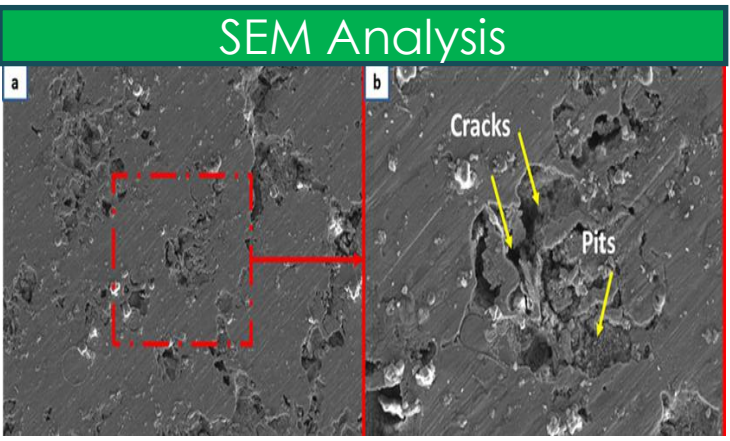


Controller

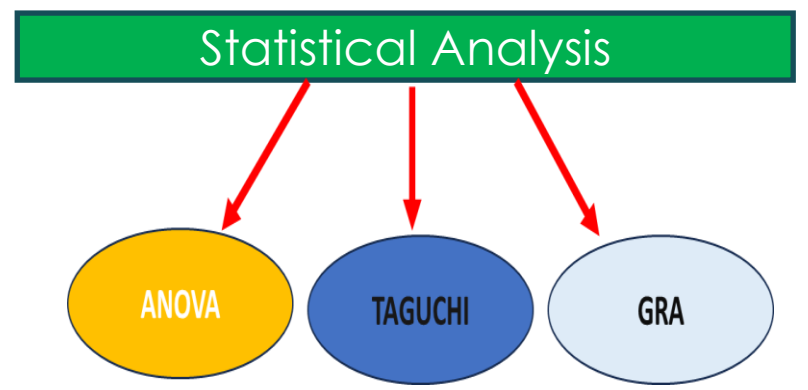
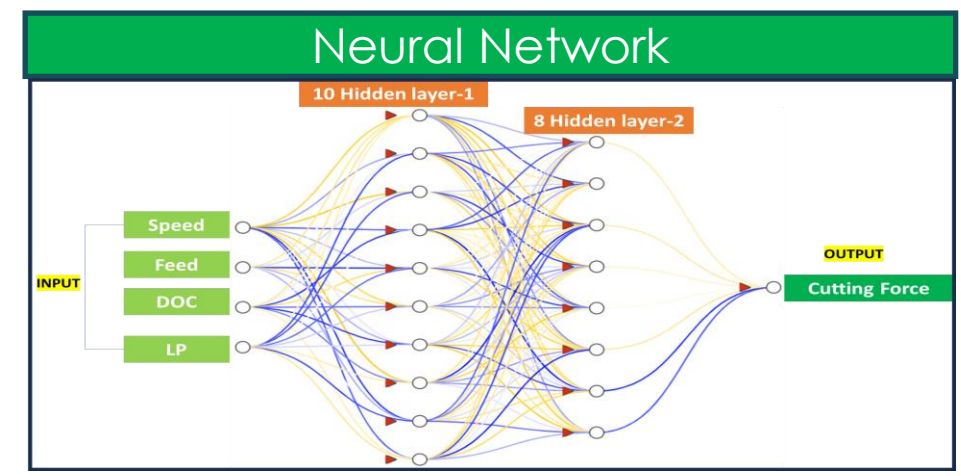
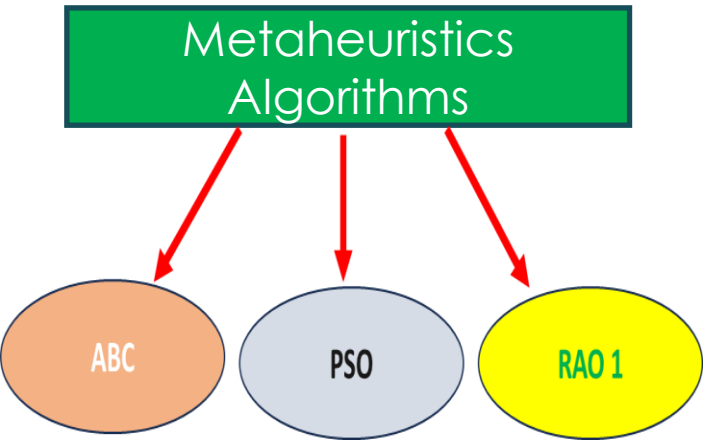


Skills Developed and Outcomes

High End Characterizations

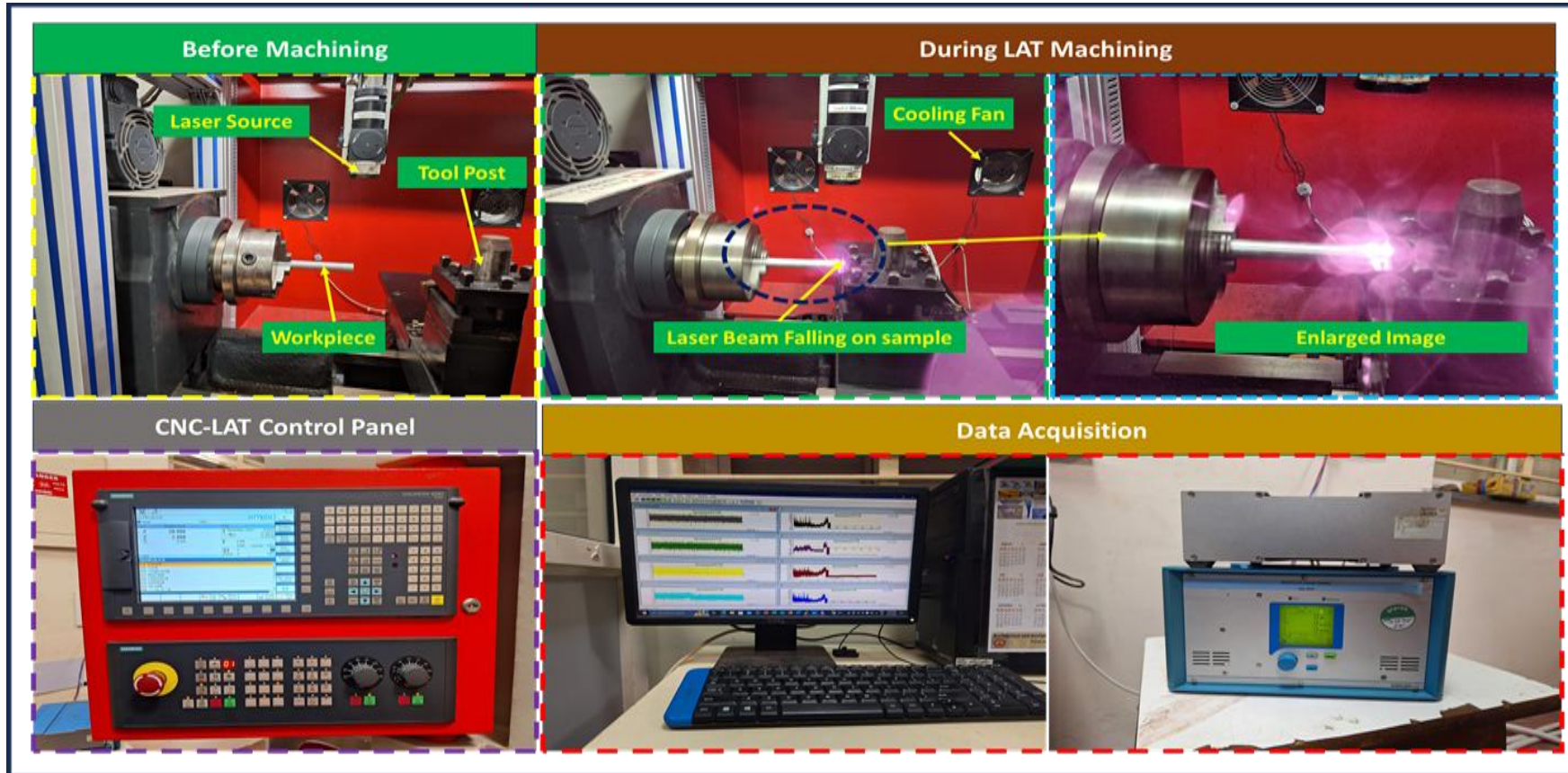


Advanced Optimization

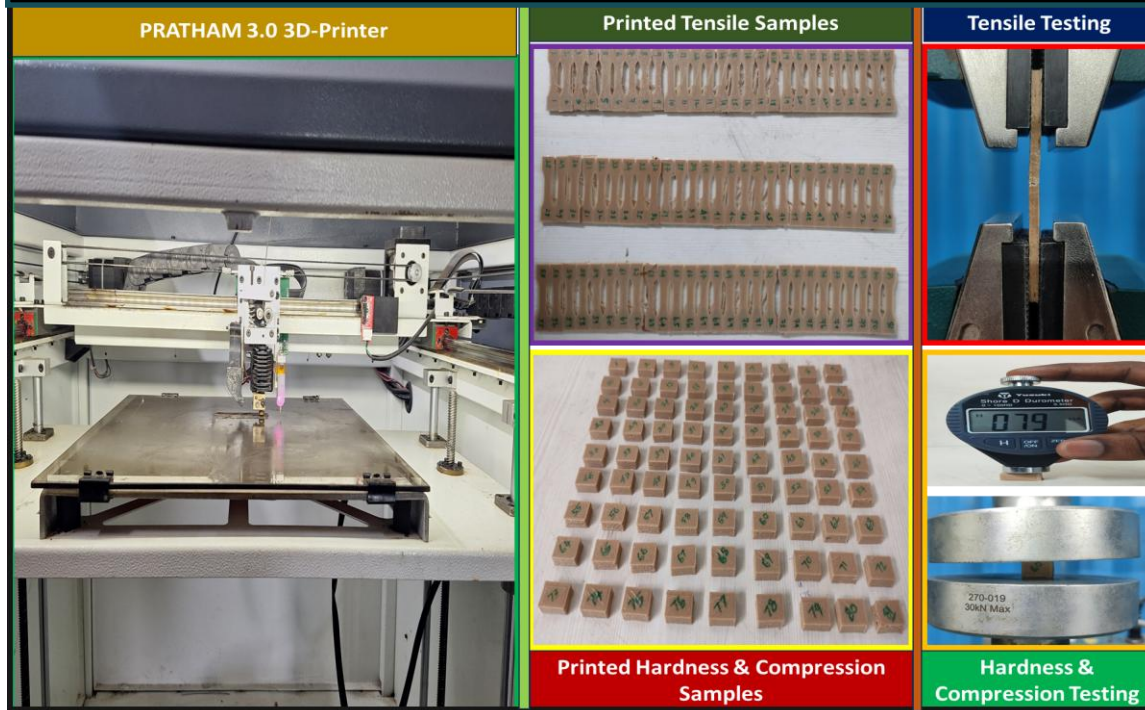


Outcomes 16 + Publications in Peer Review Journals(Q1 & Q2) and 1 Patent Granted

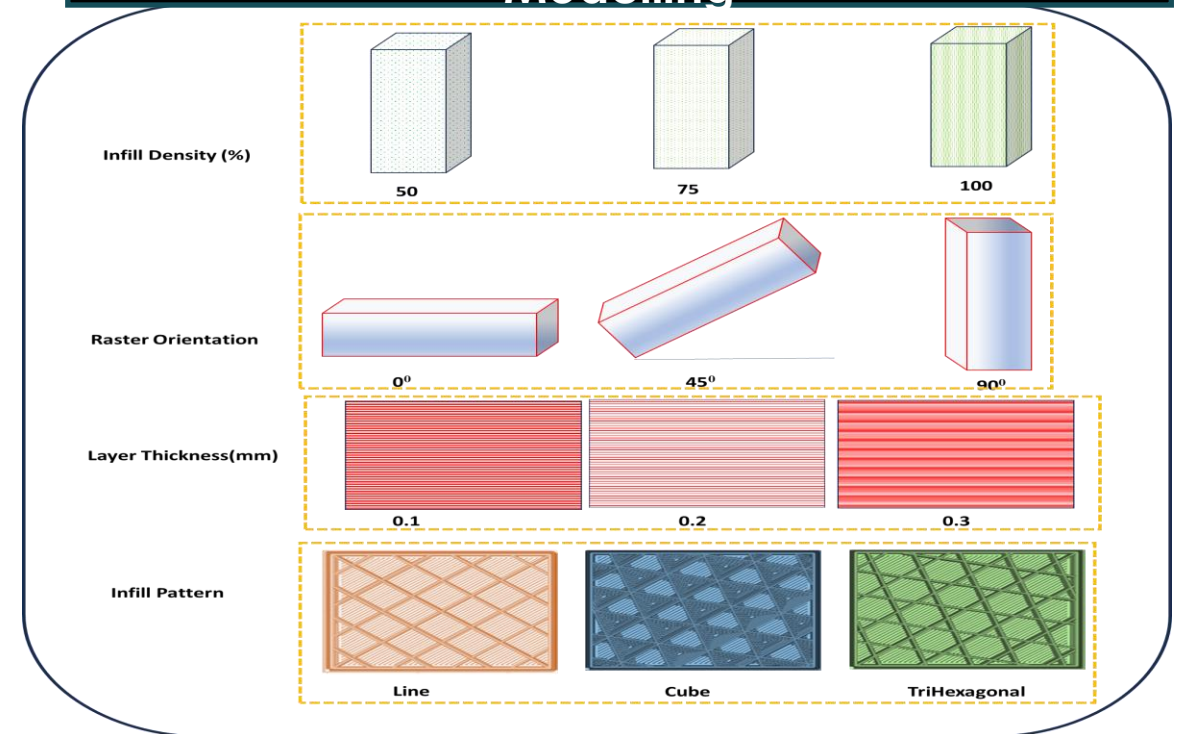
Laser Assisted Machining



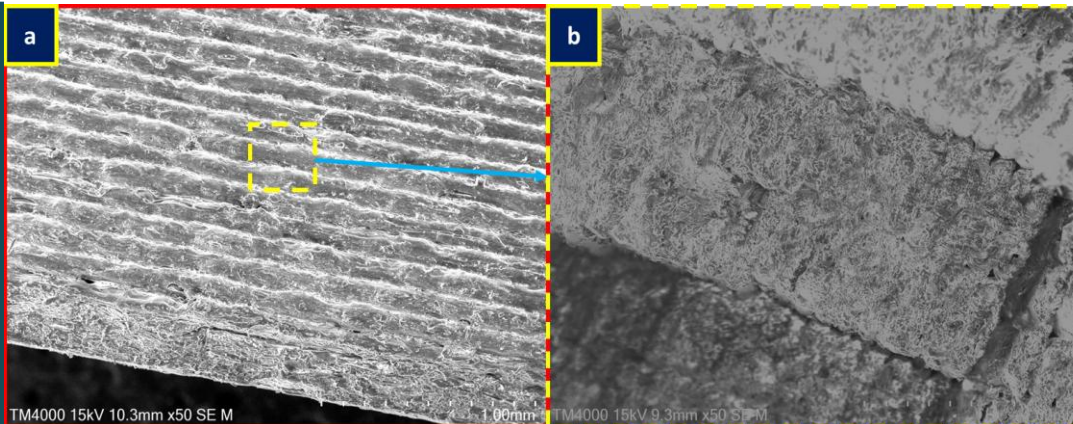
Bioinspired 3D Printing of Bamboo as a reinforcement



Process Parameter of Fused Deposition Modelling



Microstructure Characterization



Current Research Work

CRYO H_2

Problem: LH₂ tank service conditions are ~20 K with internal pressure $\approx$ 10 bar; under these **thermo-mechanical** conditions, composites can develop **microcracks and leak paths**, and a reliable lab test methodology is still low-maturity.

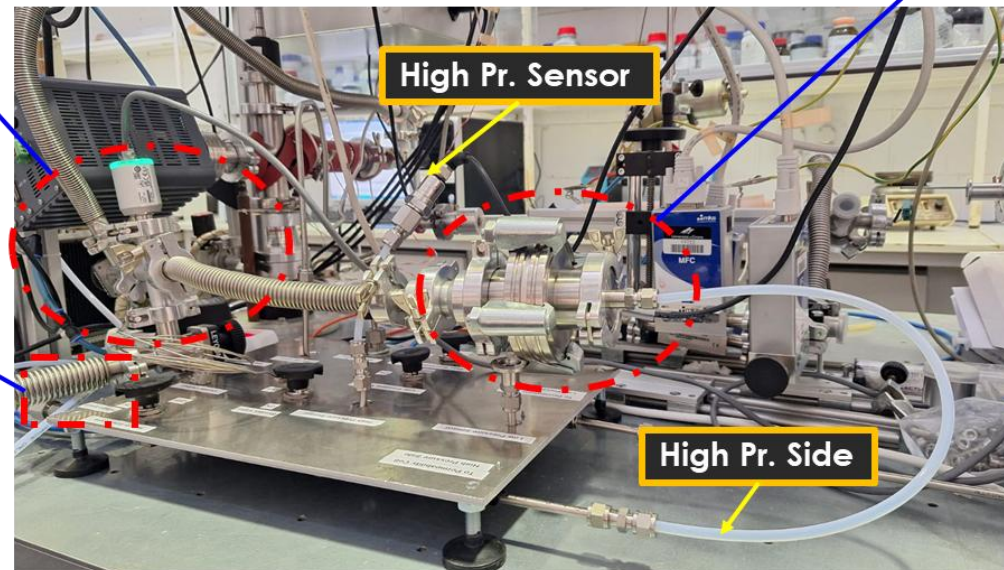
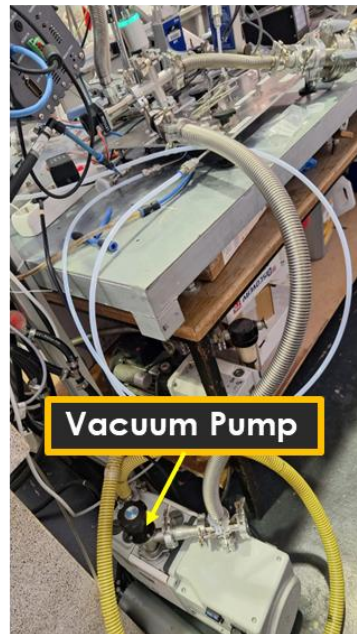
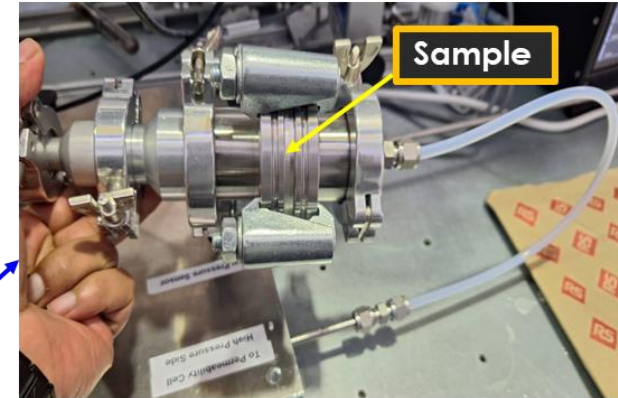
Why permeability? **Type-V** LH₂ tanks have **no liner** $\rightarrow$ the composite must act as the gas barrier; leakage is a safety/boil-off risk.

Why leaks happen? Matrix cracking/delamination (from manufacturing **residual stresses, thermal drop, fatigue/impact**) can create through-thickness gas paths.

Core idea: Develop advanced **cryogenic test methods** (integrated in a cryostat down to 20 K) to **reproduce real tank conditions** in the lab and measure key properties for LH₂ tank design.

Why biaxial loading: Tank **internal pressure produces a biaxial stress state**, so permeability must be evaluated under representative multiaxial stresses (not only uniaxial), ideally while at cryogenic temperature.

Constructed Experimental Setup



RELAX Project

- Problem:** *Residual stresses* are unavoidable during composite processing (*shrinkage + CTE mismatch + ply anisotropy*) and they strongly affect damage, yet they are often not properly included in damage predictions.
- Core idea:** Instead of only trying to *minimize* residual stresses, RELAX aims to *tailor them intentionally* (create beneficial compressive stresses) to *delay matrix cracking* and thus delay delamination and loss of performance.
- Why new matrices:** RELAX focuses on *stress-relaxing matrices* (*vitrimers + high-performance thermoplastics*) because their stress-relaxation ability enables *self-healing potential*.
- Why important (application):** For **Type-V LH₂ tanks (no liner)**, matrix cracking can create through-thickness gas paths → higher permeability/leaks, worsened by biaxial stress and the temperature drop to **~20 K**.



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