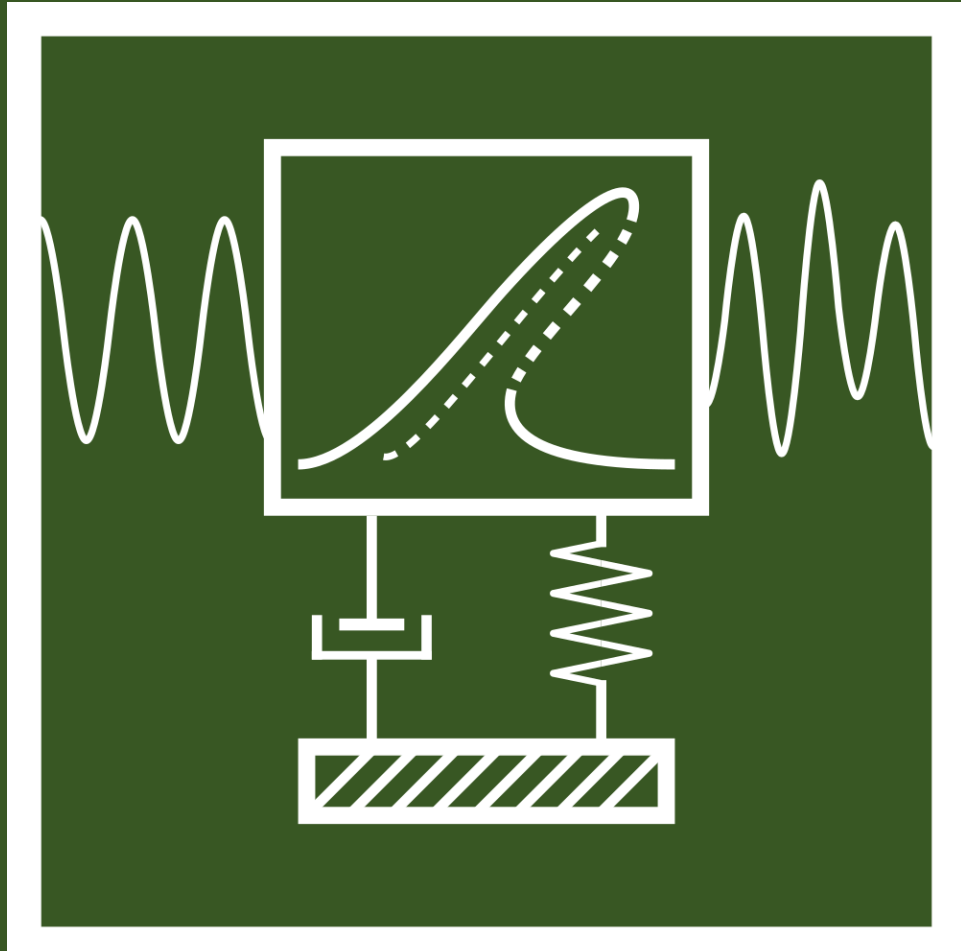


# Dynamic Mechanical and Interfacial Behavior of PLA/PEG/Flax Fiber Bio composites for Vibration Resistant Orthopedic Fixation Plates

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**A** **Abstract:** Biodegradable PLA/PEG/flax fiber composites (0–14 wt% PEG, 5–10 wt% fiber) were developed to overcome stress-shielding and vibration mismatch in metallic implants. Fiber treatment raised tensile and flexural strength/modulus by 20–30% via stronger interfacial bonding confirmed by SEM. Increasing PEG content reduced stiffness but improved impact toughness and vibration-damping capacity with intermediate PEG formulations (S3, S4) offering the best stiffness damping balance. TGA and DSC confirmed stable thermal behavior showing treatment and PEG effects were interfacial not bulk. Fiber treatment controls interfacial strength while PEG tunes the stiffness damping trade-off making moderate PEG treated composites ideal for vibration-compatible orthopedic fixation plates.

**01** **Methods:** **Blend & extrude raw materials (A–C)** Two powder/granular components (A and B) are mixed together then fed into an extrusion machine (C) that processes the blend into continuous filaments. **Form into fiber/filament and chop (C–E)** The extruded material emerges as long thin filaments/strands (D), which are then cut down into short chopped fibers (E). **Mold and press into final panel (F–H)** The chopped fibers are laid out into a mat or preform (F), placed into a hot press (G), and compression-molded to produce the final solid composite panel (H).

**02** **Results:** SEM analysis of four composite combinations revealed that fiber treatment substantially improved interfacial adhesion between flax fibers and the PLA/PEG matrix evidenced by reduced fiber pull-out and fewer interfacial gaps compared to untreated composites. This translated into measurable mechanical improvements: treated composites showed higher tensile strength and tensile modulus along with distinct stress-strain profiles. Yield strain and fracture strain values differed notably between treated and untreated groups indicating a shift toward more efficient stress transfer at the fiber-matrix interface. Thermal characterization via TGA/DTG showed changes in degradation behaviour with varying PEG content, while DSC heating-cooling cycles (first heating, first cooling, second heating) confirmed that PEG plasticization altered crystallization and thermal transition behaviour supporting tuneable stiffness-damping performance across formulations.

**03** **Discussion:** Fiber treatment enhances stress transfer by improving fiber-matrix bonding while PEG plasticization tunes stiffness-damping balance addressing vibration mismatch in metallic implants. Combined mechanical and thermal data support an optimized PLA/PEG/flax formulation as a biodegradable alternative minimizing stress-shielding and avoiding removal surgery required by conventional fixation plates.

**04** **Conclusions:** **Fiber treatment improves interfacial adhesion:** SEM comparisons of treated vs. untreated flax fiber composites show that surface treatment reduces fiber pull-out and gaps translating into better stress transfer and mechanical performance (stress-strain, tensile strength/modulus). **PEG content tunes stiffness-damping balance:** By adjusting PEG plasticizer levels alongside fiber treatment the composite's mechanical stiffness and vibration-damping behaviour can be tailored addressing the vibration mismatch problem seen in rigid metallic implants. **An optimized PLA/PEG/flax formulation offers a viable biodegradable alternative:** The combined thermal (TGA/DTG, DSC heating-cooling) and mechanical data support identifying a formulation that reduces stress-shielding and vibration mismatch compared to conventional metallic fixation plates while remaining biodegradable (avoiding removal surgery)

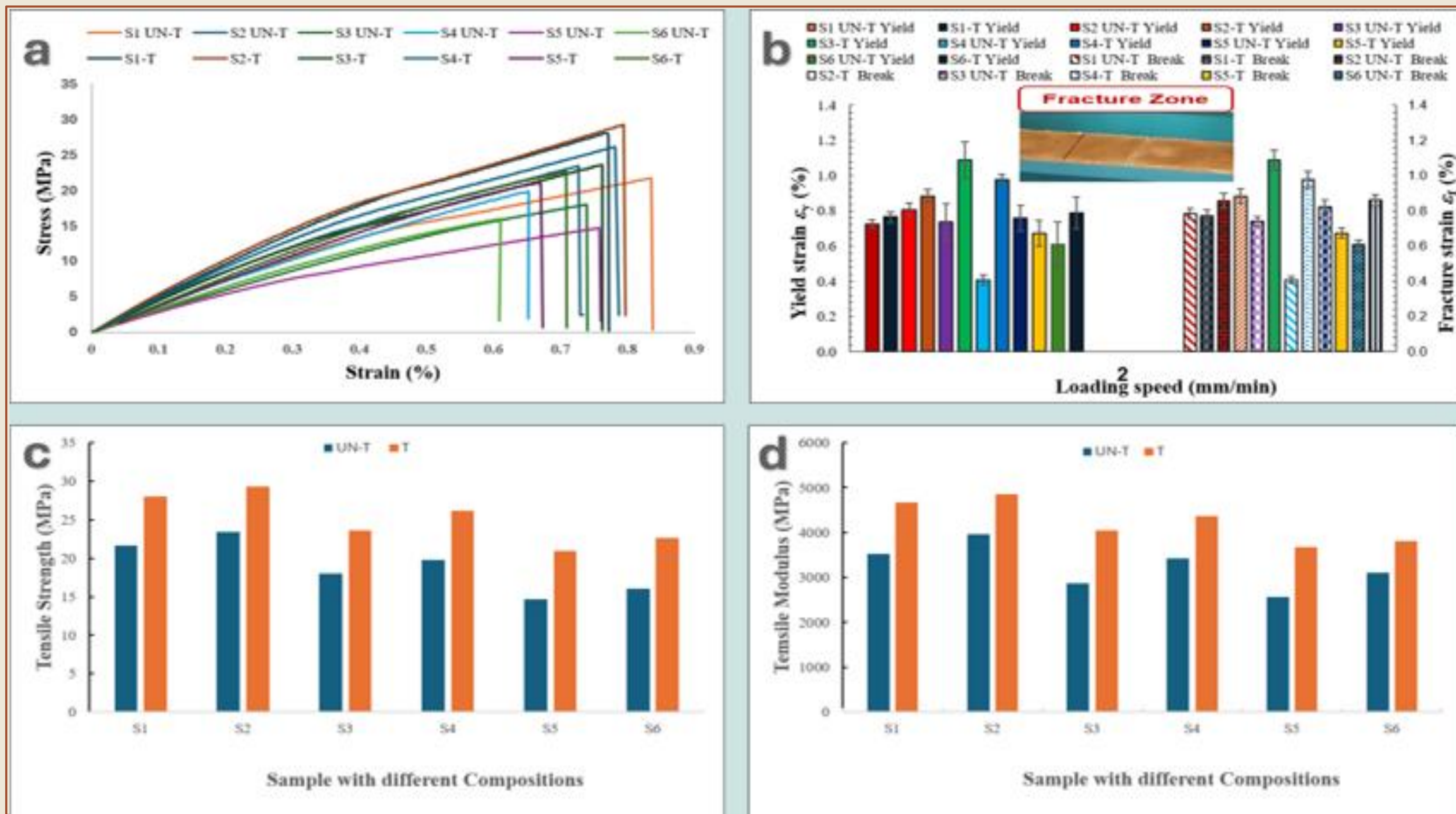


Fig 2. a) Stress vs Strain Behaviour b) Yield Strain and Fracture Strain c) Tensile strength d) Tensile Modulus

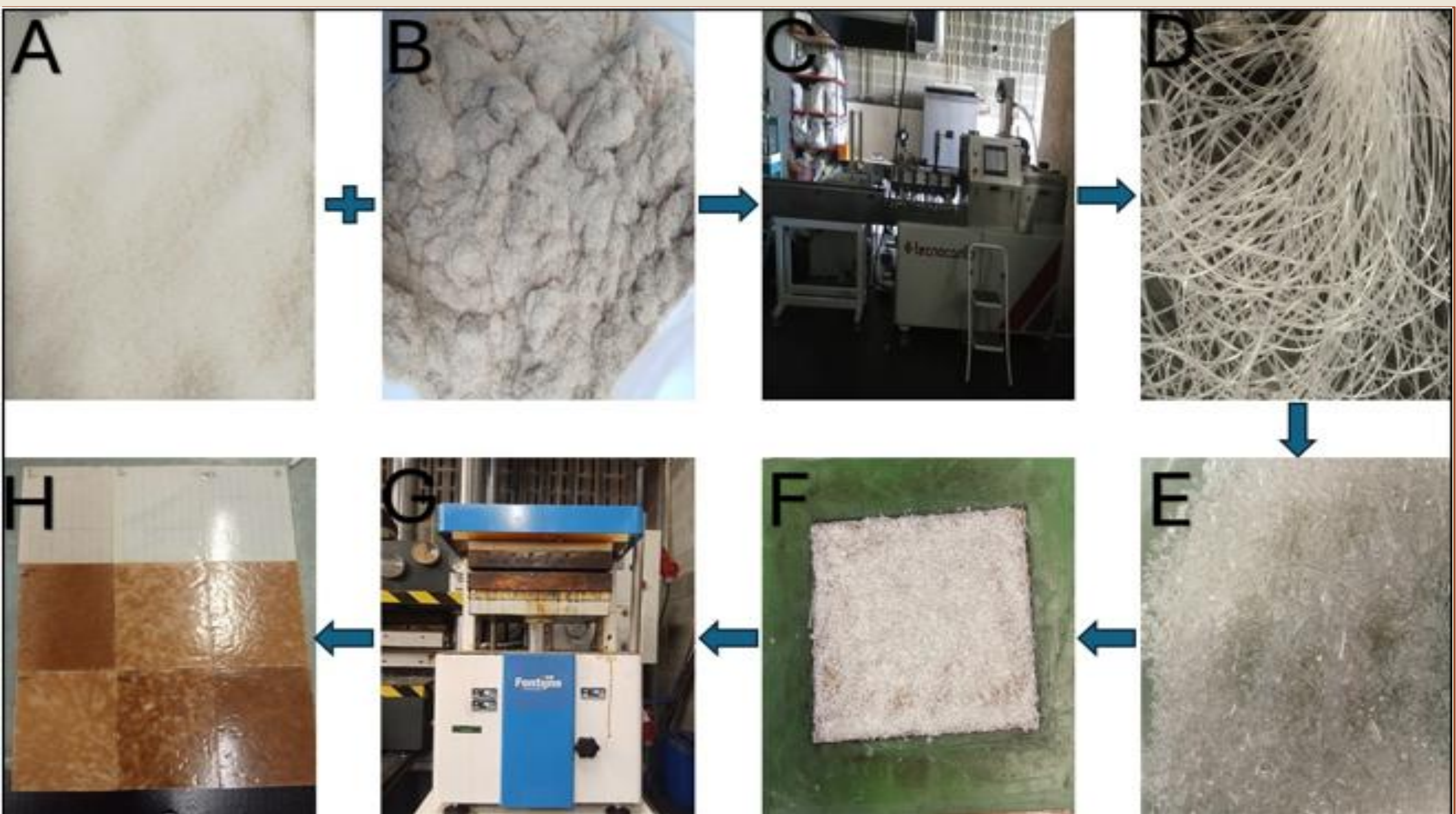


Fig 1. Schematic of the experimental set-up / model.

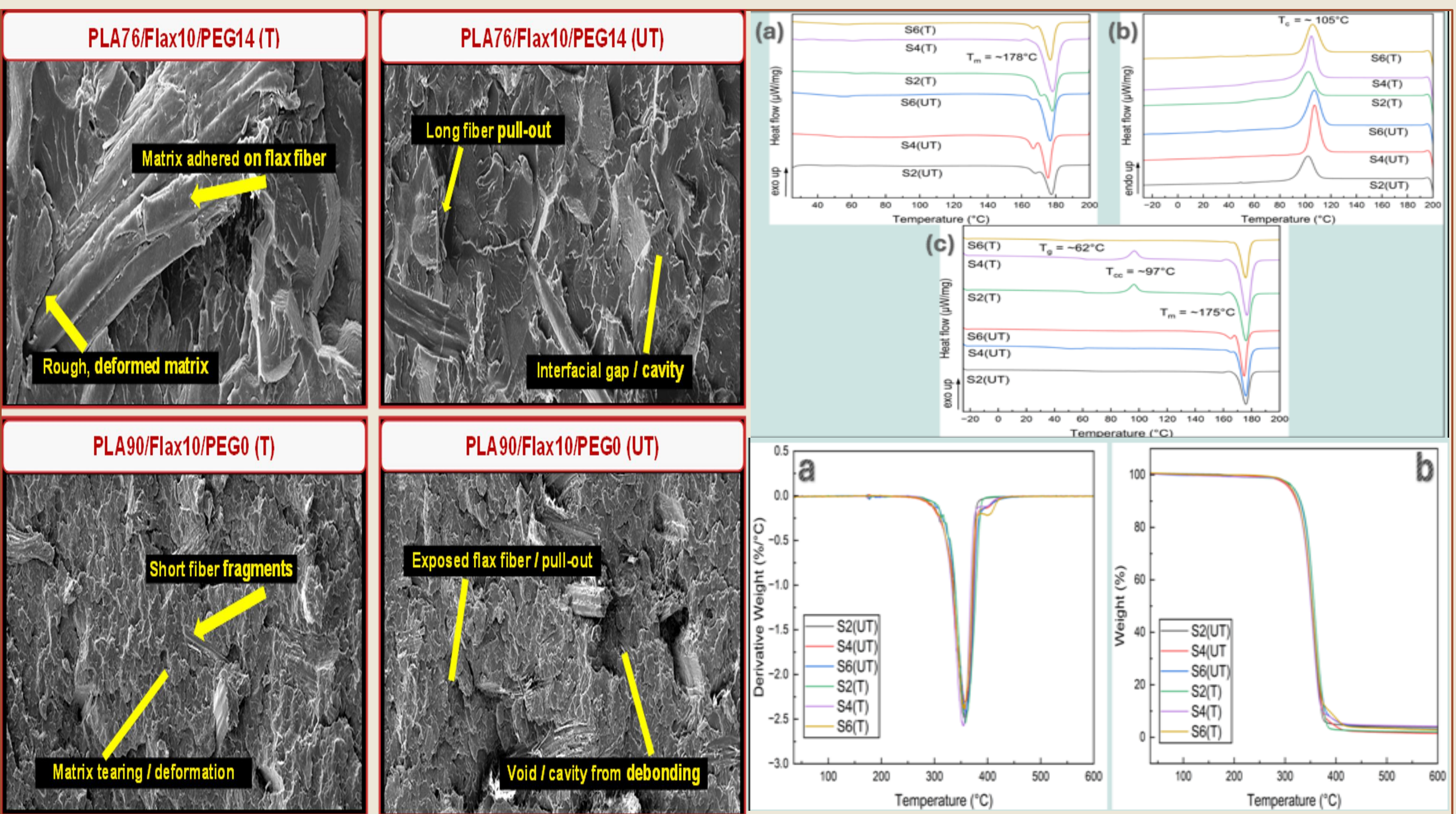


Fig 3. Scanning Electron Microscopy and Thermogravimetric Analysis

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