Microbial Enzyme-Mediated Recycling for Fibre-Reinforced Polymer Composites

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Energy and clean technology

> TRL 2-3

Executive statement
An innovative method and system utilizing microbial enzyme-mediated hydrolysis combined with pre-treatment and post-treatment processes to efficiently recycle fibre-reinforced polymers into high-quality carbon and glass fibres.

Solution
This technology presents a sustainable and cost-effective recycling process for fibre-reinforced polymers (FRP), including carbon fibre-reinforced polymer (CFRP) and glass fibre-reinforced polymer (GFRP). The process involves three main stages: a pre-treatment step using solvolysis, UV degradation, and/or oxidation to degrade the epoxy resin matrix; a microbial enzyme-mediated hydrolysis step employing fungi cultures to break down the composite matrix; and a post-treatment step involving low-temperature pyrolysis and/or electrochemical treatment to recover clean, high-performance carbon and glass fibres. The system incorporates cyclical microbial degradation with growth medium replenishment and spore activity maintenance to optimize fibre recovery while minimizing environmental impact.

Intellectual Property Status
Provisional application 2024903495

Key advantages
- Efficient separation and recovery of valuable carbon and glass fibres from composite waste.
- Cost-effective and environmentally friendly process using microbial degradation and bioacid pre-treatment.
- Closed-loop system with acid recycling and growth medium replacement to reduce operational costs and waste.
- Low-temperature pyrolysis reduces energy consumption and greenhouse gas emissions compared to traditional methods.
- Ability to recycle both CFRP and GFRP, including hybrid composites.
- Enhanced fibre quality suitable for aerospace, defense, automotive, and renewable energy applications.
- Modular system design with pre-treatment, microbial degradation, and post-treatment subsystems.
- Supports sustainable manufacturing and aligns with global environmental goals.

Problems solved
- Difficulty in recycling cured fibre-reinforced polymers due to their mixed composite structure.
- High waste volumes of CFRP and GFRP composites ending up in landfills or incineration.
- Limited domestic carbon fibre supply and reliance on imports in some regions.
- Environmental challenges related to non-biodegradable FRP waste disposal and CO_2 emissions from conventional recycling.
- Reduced mechanical properties and limited reuse options from mechanical recycling methods.
- High operational costs and waste generation in existing recycling processes.

Market applications
- Recycling of CFRP and GFRP composite waste from aerospace, automotive, construction, defense, and renewable energy sectors.
- Production of recycled carbon and glass fibres for manufacturing lightweight, high-performance composite components.
- Small to medium-sized FRP manufacturing facilities seeking cost-effective recycling solutions.
- Government and environmental organizations aiming to reduce composite waste and promote sustainable practices.
- Infrastructure projects such as wind turbine blade recycling contributing to net-zero emissions targets.
- Development of eco-friendly composite manufacturing supply chains.

Inventors
Dr Ali Hadigheh, Yaning Wei

Contact Commercialisation Office
Lulu Xue
Commercialisation Manager
Email: lulu.xue@sydney.edu.au
sydney.edu.au/innovation-and-enterprise