MIT Portugal Program 2024-25 Progress Report

Project Title: Ocean-Derived Pollution-Reducing Polyethylene-Based Fabrics for Healthcare and Space Applications
Grant Period: 08/01/2024 – 07/31/2026
Reporting Period: Year 1
PI: Svetlana V. Boriskina (MIT)
Co-PI: Raul Fangueiro (Fibrenamics, Universidade do Minho)

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1. Project Objectives and Alignment with MIT Portugal Priorities

The goal of this project is to develop degradation-resistant, recyclable polyethylene (PE)-based fibers, textiles, and additively manufactured materials for healthcare and space applications, while directly addressing microplastic pollution and textile waste at the source. The work aligns closely with MIT Portugal priority areas in advanced manufacturing, sustainable materials, blue bioeconomy, and space-enabled technologies.

During the first reporting period, the project has advanced three interconnected research thrusts originally outlined in the proposal:

1. Ionizing radiation shielding using PE-based materials compatible with additive manufacturing, relevant to space habitats and medical radiation protection;
2. Monomaterial PE yarns for circular textiles, enabling full thermo-mechanical recyclability and reduced environmental impact;
3. Engineering thermal conductivity of PE fibers and fabrics to enable passive cooling in wearable textiles for healthcare and extreme environments.

All the functional materials used in the research are polyethylene-based blends or composites, which offer high hydrogen content, chemical stability, biocompatibility, scalability, and full recyclability (via either thermo-mechanical or chemical process).

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2. Progress on Research Thrusts

2.1 Additively Manufactured PE-Based Materials for Radiation Shielding

Objective: Develop PE-based radiation shielding materials that can be fabricated via fused deposition modeling (FDM) to support in-situ manufacturing for space missions and lightweight, recyclable shielding for healthcare.

Progress and Key Results:

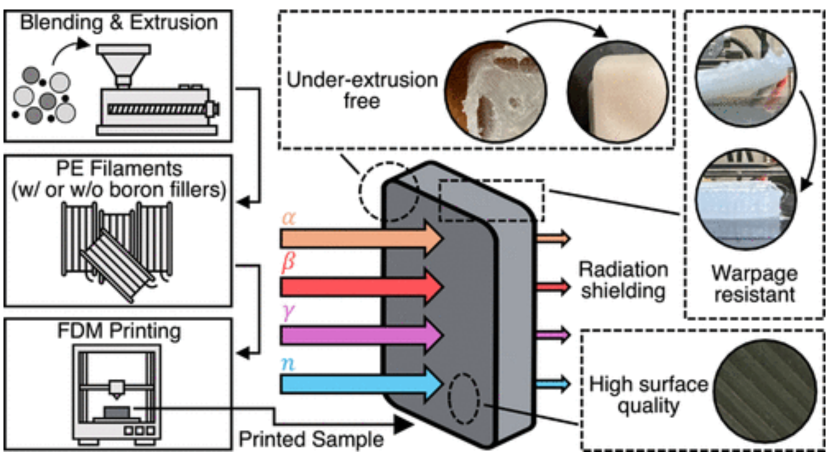
- A printable polyethylene blend was engineered to overcome longstanding challenges of PE additive manufacturing, including warpage, poor adhesion, and under-extrusion.
- The optimized PE blend was successfully processed into uniform, high-quality FDM filaments and printed across multiple commercial FDM platforms.

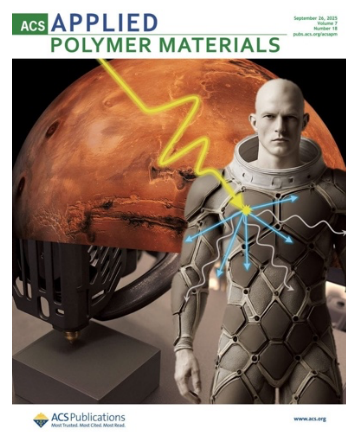
- Boron-rich fillers (boron carbide and boron nitride) were incorporated to enhance secondary neutron attenuation while preserving high hydrogen content for primary radiation shielding.
- Printed parts exhibited:
  - High density and low porosity;
  - Mechanical properties comparable to compression-molded references;
  - Stable crystallinity and polymer chain orientation post-printing.
- Radiation shielding performance was validated using:
  - Monte Carlo simulations of galactic cosmic rays, solar particle events, and secondary neutrons;
  - Neutron transmission experiments at a national neutron scattering facility.

Relevance to MIT Portugal priorities and Impact:

This work establishes a recyclable, additively manufacturable radiation shielding platform, supporting both:

- Space applications (in-situ fabrication, reduced launch mass, material reuse);
- Healthcare applications (lightweight, customizable radiation protection without toxic metals).





2.2 Monomaterial Polyethylene Yarns for Circular and Low-Waste Textiles

Objective: Replace conventional multi-polymer elastic yarns with fully recyclable, monomaterial PE-based yarns, eliminating a major barrier to textile circularity.

Progress and Key Results:

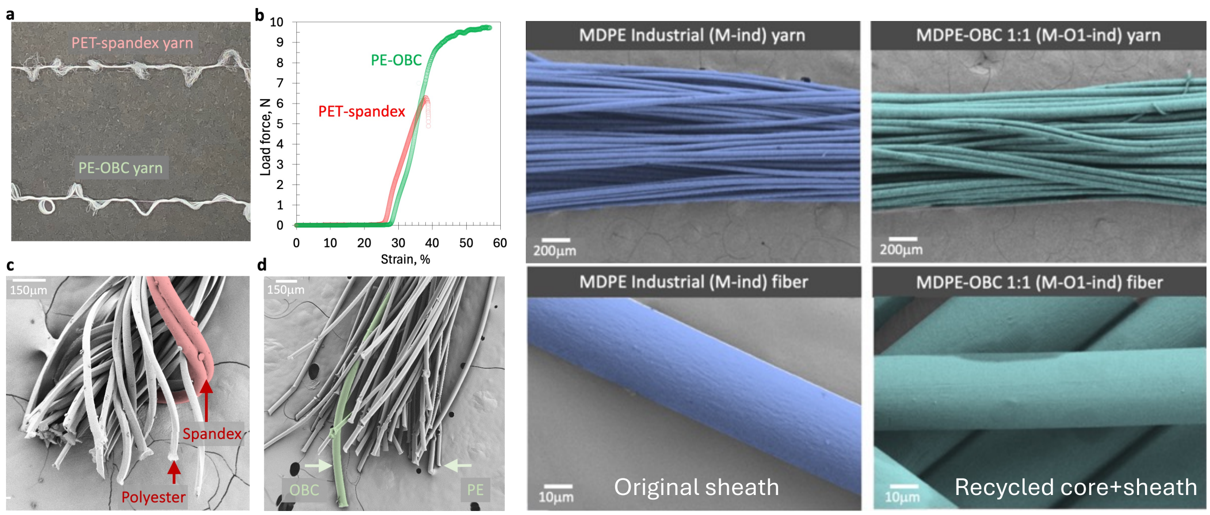
- Melt-spun PE-based fibers from fossil-derived and bio-derived materials were engineered to span a wide range of mechanical properties, from highly elastic to high-tenacity, by controlling polymer chemistry, crystallinity, and molecular orientation.
- Elastic core–sheath yarns were fabricated entirely from PE-based materials:
  - Olefin block copolymer (OBC) monofilament cores for elasticity;
  - High-density PE multifilament sheaths for strength and durability.

- The resulting yarns:
    - Match or exceed the elastic recovery of commercial spandex–polyester yarns;
    - Support higher tensile loads;
    - Exhibit stable cyclic performance over large strains.
- Because all components are thermoplastic polyolefins, the yarns are fully thermo-mechanically recyclable without polymer separation.

Relevance to MIT Portugal priorities and Impact:

This work directly addresses textile waste and microplastic pollution, a major environmental challenge for Portugal's textile industry. The technology enables:

- Circular medical textiles (compression garments, bandages, orthopedic supports);
- Durable, recyclable garments for performance and space applications;
- Compatibility with existing high-throughput textile manufacturing infrastructure in Portugal.



2.3 Thermally Conductive PE Textiles for Passive Cooling

Objective: Enable passive personal cooling through PE textiles by engineering thermal conductivity and fabric architecture, without relying solely on infrared transparency.

Progress and Key Results:

- Axial thermal conductivity of PE fibers was enhanced via melt-spinning and drawing-induced polymer chain alignment.
- Monomaterial knitted PE fabrics were engineered to maximize:
    - Skin–fabric contact;
    - In-plane and through-plane thermal conductance;
    - Thermal effusivity (cool-touch sensation).
- Controlled "artificial skin" experiments demonstrated:
    - Initial skin temperature reduction of up to 1.5 °C below bare-skin steady state;

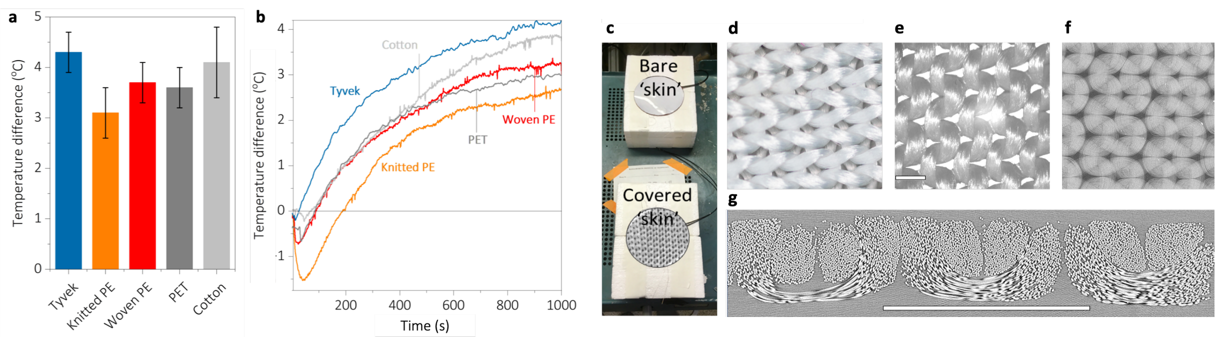
- Sustained steady-state reductions of 0.6–1.4 °C relative to cotton and polyester fabrics.

- Conductive cooling remained effective under direct skin contact and wet conditions, complementing evaporative cooling mechanisms.

Relevance to MIT Portugal priorities and Impact:

The results support development of:

- Cooling medical garments that improve patient comfort and compliance;
- Passive thermal management solutions for space habitats and undergarments;
- Energy-saving textiles that reduce reliance on active HVAC systems.



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3. Integration Across Thrusts

The three research thrusts are tightly integrated through:

- A shared polyethylene materials platform;
- Common melt-processing and textile manufacturing routes;
- Unified sustainability goals emphasizing recyclability, durability, and reduced pollution.

Together, they demonstrate that PE can serve as a multifunctional material system addressing radiation protection, circular manufacturing, and thermal comfort, capabilities traditionally achieved using dissimilar, non-recyclable materials.

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4. Collaboration and Impact on Portugal

The project builds directly on collaboration between MIT and Fibrenamics / Universidade do Minho, leveraging complementary expertise in polymer physics, textile engineering, and sustainable manufacturing. Outcomes support Portugal's leadership in:

- Advanced textile manufacturing;
- Blue bioeconomy and marine pollution mitigation;
- High-value technical textiles for healthcare and aerospace markets.

The work complements the "Pacto Bioeconomia Azul" initiative by advancing scalable pathways for incorporating sustainable polymer technologies into existing value chains.

5. Outputs and Next Steps

Outputs to Date:

- Three peer-reviewed manuscripts (published or under review);
- Validated materials, yarns, and textile prototypes;
- Demonstrated scalability via conventional extrusion, spinning, knitting, and FDM printing.

Next Steps:

- Integration of ocean-derived PE and algae feedstocks;
- Expanded durability and environmental exposure testing;
- Joint prototyping and scale-up with Portuguese partners;
- Translation toward demonstrator garments and functional components.

Publications:

1. D. Xu, V. Korolovych, Y. Lyu, J. Aslarus, D.R. Flores-Hernandez, S. Pajovic, W. Heller, L. Sihver, S.V. Boriskina, Warpage Resistant, Under-extrusion Free, High Surface Quality Additive Manufacturing Process for Polyethylene-Based Composite Radiation Shielding Material, **ACS Applied Polymer Materials**, *7* (18), 12304-12320, 2025 [COVER].
2. M. Alberghini, et al, Thermally conductive polyethylene fabrics for enhanced passive cooling via a scalable monomaterial technology, in preparation.
3. S.-H. Kim, et al, Polyethylene-based thermo-mechanically recyclable elastic yarns for circular sustainable textiles, in preparation.