Laboratory of Sustainability Robotics

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Title	Mushroom drones for environmental exploration		
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Laboratory / Institution	Laboratory of Sustainability Robotics EPFL ENAC IIE (Lausanne) and Empa (Dübendorf, Zurich)		
Research Site	GR B2 390, EPFL ENAC IIE LSR		
Project Period	01.07.2026 - 31.12.2026 (To be discussed)		
Contact	kyung-sub.kim@epfl.ch (Dr. Kyung-Sub Kim)		
Requirements	*The student belongs to EPFL*. The student is motivated to work on an interdisciplinary research topic encompassing material/electrical/ environmental/mechanical science & engineering.		

Figure 1. Image of mushroom (mycelium and fruiting bodies) (left)[1] and previously reported biological UAV made of fungus-like materials (right)[2].

Introduction

The adoption of biodegradable materials in electronics and robotics can help mitigate the ecological footprint caused by the multidisciplinary applications of intelligent devices. In this context, transient robotics composed of biodegradable materials has attracted increasing attention, offering potential applications in various fields such as medical robotics, environmental exploration, and agriculture[3]. Exploratory transient robots can float on water[4], crawl through soil[5], or fly into dense forests[6], and after completing their missions, they can decompose into non-toxic byproducts in the natural environment. These robots have been fabricated using biodegradable polymers such as gelatin, lignin, PLA, and cellulose, which are degraded into short polymer chains by esterases produced by soil microorganisms.

However, the environmental conditions to which devices are exposed at their end-of-life stage, such as temperature, humidity, pH, and microbial activity, are not constant. As a result, the degradation rate of the devices cannot be guaranteed within a predictable range, and the pathways of their return to the natural environment remain uncertain. By employing **bio-hybrid composites containing living**

mycelium, it becomes possible to **pre-program their life cycle** by controlling the species and concentration of the mycelium. Furthermore, using wood chips as fillers in mycelium composites can simplify the fabrication process and reduce material and processing costs. Beyond this, properties such as **self-healing capability, environmental adaptability, and the ability to generate electrical signals in response to environmental stimuli** make mycelium-based materials highly promising for expansion into robotic applications such as robotic skin[7] and controllers[8].

Although mycelium–woodchip composites are highly promising, systematic material studies on their mechanical and electrical properties, as well as their biodegradation kinetics depending on different combinations of mycelium and wood chips, are still lacking. Moreover, in the implementation of robotic structures, biologically driven fabrication methodologies remain a missing piece. Therefore, **this project focuses on fundamental material, mechanical, and biological studies of mycelium–wood composites for the realization of eco-monitoring transient robotics.**

Objectives

- Development of mycelium–woodchip hybrid composites and optimization of their mechanical properties and biodegradability
- Development of a transient drone platform for environmental monitoring through optimization of composite fabrication methods
- Development of an external stimulus sensing platform through electrode integration within the composites and optimization of the electrode structure

Work breakdown

- Literature review
  - Types of mycelium-hybrid composites, Mycelium cultivation methods, and equipment
  - Evaluation methods for morphological changes and mechanical properties of mycelium–wood composites
- Experimental training
  - Laboratory safety training and training on equipment operation (incubator, mixer, autoclave, laminar flow hood, laser cutting machine, 3D printer, etc.)
  - Training on characterization systems, structural design, and visualization software (Origin, ImageJ, Arduino, AutoCAD, Tinkercad, Rhino, KeyShot, etc.)
  - Acquisition of fundamental composite fabrication skills (fungi culture, sterilization, PDMS moulding, laser patterning, etc.)
- Material optimization
  - Development and optimization of mycelium cultivation processes on woodchips (Fig. 2)
  - Mechanical property optimization through additive selection and blending

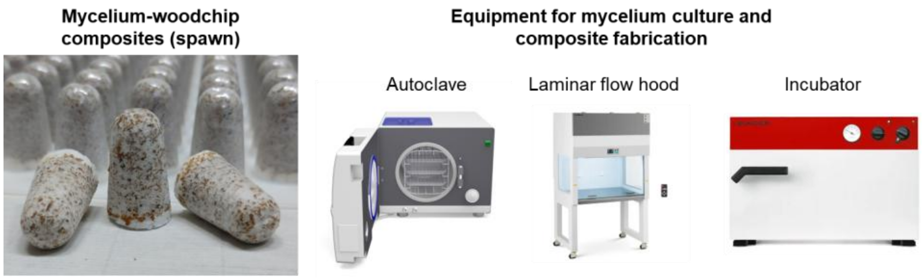

Figure 2. Image of the mycelium-woodchip composites (left) and the equipment required for the composite fabrication (right).

- Optimization of composite materials capable of generating electrical signals sensitively in response to light and thermal stimuli
- Evaluation of morphological changes and wood degradation using OM and SEM imaging
- Optimization of biodegradability and environmental stability under various conditions

➢ Device fabrication
- Fabrication of mycelium–wood composite structures using moulding and/or 3D printing
- Integration of embedded electrodes into composite structures for sensing applications
- Fabrication of lightweight glider wings and structures for transient drone platforms

➢ System demonstration
- Conceptual demonstration of an eco-monitoring transient drone platform using moulded glider wings and mycelium-based composite structures

➢ Report writing
- Acquisition of knowledge on report writing and presentation material preparation

References

[1] URL: https://stock.adobe.com/kr/images/homemade-mushrooms-and-mycelium-champignon-mushrooms-growing/194266646

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[5] S. Mariani et al., An autonomous biodegradable hygroscopic seed-inspired soft robot for visual humidity sensing. *Mater. Des.* **235**, 112408 (2023)

[6] F. Wiesemüller et al., Biopolymer Cryogels for Transient Ecology-Drones. *Adv. Intell. Syst.* **5**, 2300037 (2023).

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[8] A. K. Mishra et al., Sensorimotor control of robots mediated by electrophysiological measurements of fungal mycelia. *Sci. Robot.* **9**, eadk8019 (2024)