Empa EPFL
Laboratory of Sustainability Robotics

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Title	Biodegradable rotary motors for eco-friendly transient drones		
Supervisor	Prof. Dr. Mirko Kovac	**Advisor**	Dr. Kyung-Sub Kim
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.		

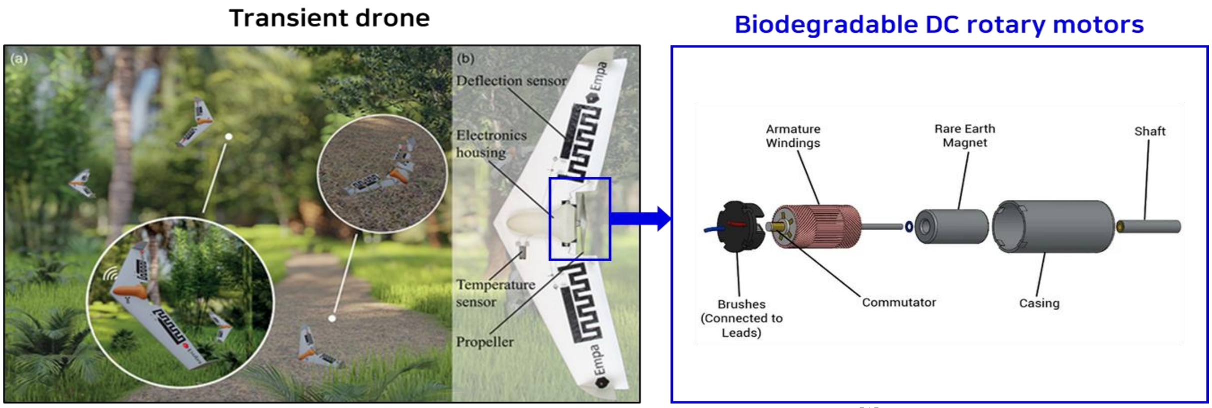

Figure 1. Images of a transient drone for environmental monitoring (left)[1] and various components of a biodegradable rotary motor used in the drone (right).

Introduction

According to a UN report, global **electronic waste reached 62 million tons** in 2022 alone, and 80% of it is not recycled, leading to severe soil and marine pollution[2]. With the recent remarkable advances in robotics, the deployment of robots is increasing at a pace comparable to that of electronic devices, and the risk of robotic waste becoming a serious environmental issue in the near future is steadily growing. To address this problem, **transient robotics composed of biodegradable materials has attracted increasing attention**, offering potential applications in various fields such as medical robotics, environmental exploration, and agriculture[3-5]. Exploratory robots can swim in the deep sea, crawl through soil, or fly into dense forests, and after completing their missions, they can decompose into non-toxic byproducts in the natural environment. Such scenarios, where materials and operating environments are precisely matched to maximize sustainability, make exploration one of the most promising application areas for transient robotics.

Recently, a microfibrillated cellulose/gelatin-based **transient drone** demonstrated for the first time the feasibility of **short-term, large-area environment monitoring**[1]. However, in order to achieve fully biodegradable transient drones, the **development of a biodegradable DC motor remains a missing piece**. One of the key components of a motor, the electromagnetic coil, requires a biodegradable conductive wire. This can be realized by coating dissolvable metal wires such as Mo or W with biodegradable polymers, but it requires careful engineering considerations, including the selection of thermally stable biodegradable polymers, polymer processing methods, viscosity control through filler loading, and winding speed control.

In this project, we propose the implementation of a **biodegradable motor based on biodegradable electrical wires and biodegradable magnetic materials**. To achieve this goal, various biodegradable magnetic materials should be systematically explored, and coating technologies for biodegradable conductive wires used in electromagnet fabrication must be developed. Optimization of the motor structure and design is an essential factor for realizing high-efficiency biodegradable device systems as well. Ultimately, **this project aims to realize a fully biodegradable aerial robotic platform through the integration of a biodegradable drone frame and biodegradable motor.**

Objectives

- Coating of biodegradable conductive wires and achievement of commercial-level electromagnet performance
- Exploration of biodegradable hard magnetic materials and optimization of biodegradable magnet fabrication processes
- Optimization of biodegradable motor design and structure
- Implementation of an integrated system combining a biodegradable motor and drone frame

Work breakdown

- Literature review
  - Structure, operating principles, and characteristics of DC motors
  - Biodegradable materials for wire insulation and magnet fabrication, as well as their thermal, mechanical, and electromagnetic properties
- Experimental training
  - Laboratory safety training & training on equipment operation (UV lamp, mixer, vacuum oven, fume hood, laser cutting machine, 3d printer, etc.)
  - Training on measurement systems, device design, and visualization software (Origin, NI, Arduino, AutoCAD, Tinkercad, Rhino, KeyShot, etc.)
  - Acquisition of fundamental 3d structure fabrication skills (PDMS moulding, release coating, conductive wire connection methods, etc.)

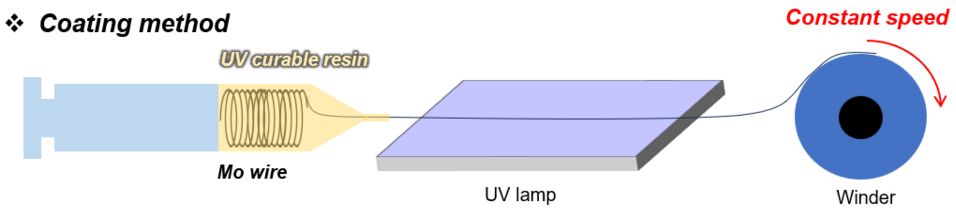

Figure 2. Schematic of the wire coating method. This is an example of one possible approach and may be modified depending on the research direction.

- Material optimization
  - Viscosity optimization of biodegradable coating materials and evaluation of coating quality using OM and SEM imaging
  - Characterization of electromagnetic properties and thermal lifetime depending on metal wire diameter, coating thickness, and number of coil turns
  - Coercivity optimization of biodegradable magnetic inorganic–polymer composites
- Device fabrication
  - Development and optimization of biodegradable wire coating technology (Fig. 2)
  - Fabrication of biodegradable magnets with magnetic particles, polymer matrix, and PDMS moulding.
  - Fabrication of a biodegradable motor through integration of biodegradable wires with biodegradable magnets, casing, brushes, and shaft components
- System demonstration
  - Integrated demonstration of a fully biodegradable aerial robotic platform through the integration of a biodegradable drone frame, biodegradable motor, and biodegradable battery
- Report writing
  - Acquisition of knowledge on report writing and presentation material preparation

References

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

[2] ITU & UNITAR, Global E-waste Monitor, Geneva/Bonn (2024).

[3] F. Hartmann et al., The New Frontier in Soft Robotics. *Adv. Mater.* **33**, 2004413 (2021).

[4] K.-S. Kim et al., Biodegradable yet hyperdurable robotic fingers for zero-waste soft electronics. *Nat. Sustain.* (2026).

[5] K.-S. Kim et al., Toward Advanced Degradable Soft Robotics Incorporating Transient Soft Electronics: Materials, Fabrication, and Applications. *Adv. Electron. Mater.* **12**(1), e00400 (2025)