Laboratory of Sustainability Robotics

EPFL ENAC IIE
1015 Lasuanne
Switzerland

Title	Biodegradable wireless communication device for environmental monitoring		
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.		

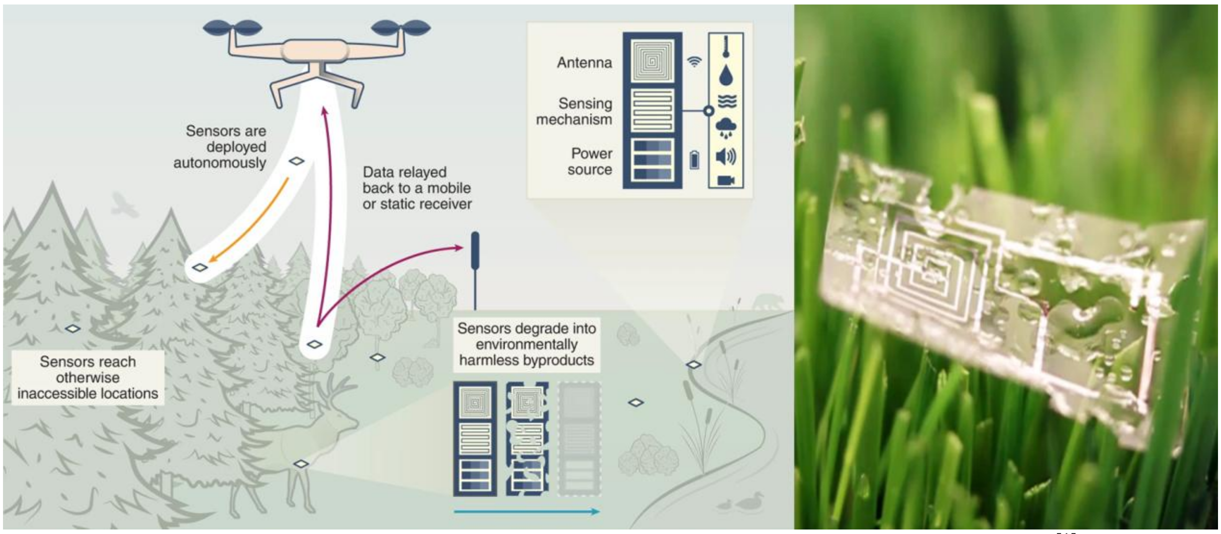

Figure 1. Overall schematic of the distributed deployment of biodegradable sensors (left)[1] and the degradation of a biodegradable sensor (right)[2].

Introduction

The importance of distributed environmental monitoring systems for real-time detection of climate change, soil contamination, water quality variation, and ecological abnormalities is rapidly increasing. Accordingly, extensive research has been conducted on **wireless sensor networks, miniaturized electronic devices, and drone-based distributed deployment and data collection technologies.** However, in natural environments such as forests, agricultural fields, oceans, and disaster areas, retrieving deployed devices is often impractical, making **electronic waste (e-waste) a growing environmental concern**. To address this issue, increasing attention has been directed toward biodegradable and transient electronics that can naturally decompose after completing their operational lifetime[1,3].

Recent advances in biodegradable electronics have demonstrated sensors[4], batteries[5], antennas[6], and logic circuits[7] based on materials such as cellulose, silk, poly(lactic acid) (PLA), gelatin, biodegradable conductive polymers, and transient metals. These devices can degrade under environmental conditions including moisture, microbial activity, and chemical exposure, showing strong potential for applications in environmental monitoring and disposable electronic systems. However, most current biodegradable electronic platforms are limited to sensing or passive device functions, while l**ong-range wireless communication remains challenging due to the dependence of conventional systems on integrated circuits and semiconductor chips**[1,3].

In this work, we propose a **chipless wireless environmental monitoring platform that integrates biodegradable sensors, batteries, antennas, and oscillators**. Instead of relying on complex digital circuits, the proposed system directly generates **electromagnetic signals using oscillator-based architectures**. Environmental information can be encoded through variations in oscillator frequency induced by changes in sensor resistance, capacitance, or resonance characteristics, enabling wireless data transmission without semiconductor chips. To realize this platform, biodegradable functional materials will be employed to integrate sensing, energy storage, and wireless transmission components, while systematically investigating their electrical performance, oscillation stability, antenna characteristics, and biodegradation behavior. Ultimately, this study aims to establish a new strategy for biodegradable wireless electronics for future large-scale eco-monitoring sensor networks and transient robotic systems.

Objectives

- Implementation of a Colpitts oscillator using conventional electronic components
- Replacement of oscillator components with biodegradable materials and devices
- Realization of a fully integrated biodegradable system consisting of biodegradable sensors, batteries, oscillators, and antennas

Work breakdown

- Literature review
  - The circuit principles and operating mechanisms of Colpitts oscillators
  - Materials, design, and fabrication methods for existing high-performance biodegradable electronic components
- Experimental training
  - Laboratory safety training
  - Training on equipment operation (homogenizer, fume hood, vacuum oven, spin coater, real-time resistance measurement system, 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 biodegradable electronic device fabrication skills (glass surface treatment, thin-film substrate fabrication methods, conductive wire connection methods, etc.)

➢ Material optimization
- Conductivity optimization of biodegradable metal–polymer composites
- Bandgap optimization of biodegradable semiconductor–polymer composites

➢ Device fabrication
- Implementation of oscillator circuits generating electromagnetic signals using commercial capacitors, inductors, and transistors
- Fabrication of biodegradable capacitors, inductors, and transistor devices through screen printing and implementation of biodegradable oscillator circuits
- Fabrication of biodegradable batteries, antennas, and sensors

➢ System demonstration
- Implementation of a receiver matched to the operating frequency of a fully biodegradable data transmitter
- Evaluation of long-range wireless data transmission capability of the receiver

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

References

[1] Sarab S. Sethi et al., Biodegradable sensors are ready to transform autonomous ecological monitoring. Nat. Ecol. Evol. **6**, 1245-1247 (2022)

[2] URL: https://www.endoacustica.com/blogen/2012/10/25/biodegradable-electronics/?srsltid=AfmBOor9OvBJ7htB1_9UZ8rIEmpwK2Y2Bf2BD1_vAxeiJahx8IoexgEg

[3] K.E. Madsen et al., Materials advances for distributed environmental sensor networks at scale. *Nat. Rev. Mater.* **11**, 26-49 (2026)

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

[5] X. Huang et al., A Fully Biodegradable Battery for Self-Powered Transient Implants. *Small* **14**(28), 1800994 (2018).

[6] S.-W. Hwang et al., Materials for Programmed, Functional Transformation in Transient Electronic Systems. *Adv. Mater.* **27**(1), 47-52 (2014)

[7] S.-W. Hwang et al., Materials for Bioresorbable Radio Frequency Electronics. *Adv. Mater.* **25**(26), 3526-3531 (2013)