Biomaterials for Prototyping in HCI

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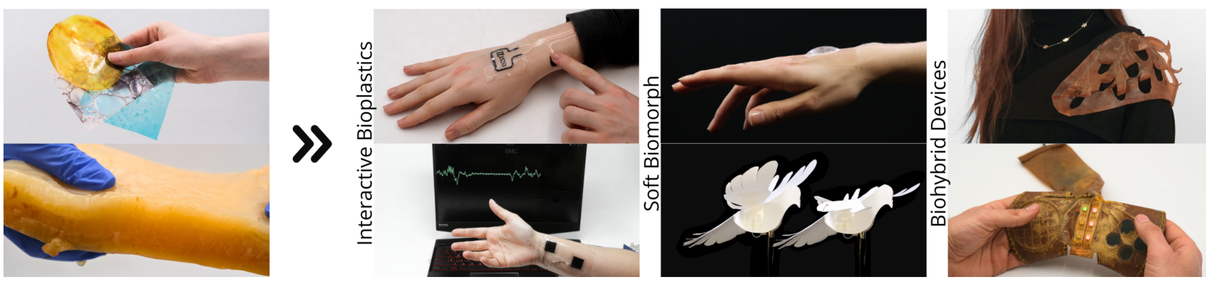

Figure 1: We demonstrate how bio-based and bio-degradable materials such as bioplastics and bacterial cellulose can be used for prototyping sustainable interactive devices through bio and digital fabrication.

Abstract

While prototyping is a widespread practice among researchers, creating sustainable, functional devices remains challenging due to the limited range of available tools and materials. We present several approaches to sustainable prototyping of functional devices. Our methods range from using bio-based and bio-degradable materials as sustainable alternatives to biologically growing electronic substrates. These methods enable a new class of interactive devices that integrate electronic components with sustainable materials. Our research on **Interactive Bioplastics** [1] introduces a DIY approach for producing conductive bioplastics that are compatible with digital fabrication techniques. Furthermore, **SoftBioMorph** [2] introduces an integrated fabrication framework for sustainable soft shape-changing interfaces made of bioplastics. Finally, our work on **Biohybrid Devices** [3] showcases how the biological growth of living bio-materials–such as Bacterial Cellulose–can be used as assembling and embedding process for electronics. In addition to presenting various artifacts, we highlight the processes introduced by our fabrication frameworks [1–3] and engage the audience in discussions about the life-cycle phases of producing artifacts, promoting a critical reflection of sustainable practices in prototyping.

CCS Concepts

• Human-centered computing → Human computer interaction (HCI); **• Hardware → Emerging technologies**.

Keywords

biomaterials, sustainability, fabrication, bioplastics, biopolymers, bacterial cellulose

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1 Introduction

Sustainability has emerged as a critical dimension in HCI, questioning our current design and fabrication paradigms, which are often agnostic to sustainability constraints. Sourcing of materials, production of electronic waste, and the life cycle of products in prototyping are core questions that need to be addressed. The tension between traditional HCI prototyping methods and sustainable alternatives calls for the development of new materials, processes, and overall mindsets that adhere to sustainable principles.

While other fields such as material science offer promising directions for bio-based materials, their integration into DIY prototyping is limited due to specialized skills, tooling, knowledge about processes and materials required. Aligning with the pressing need for a shift toward sustainable design and fabrication, our work aims to lower the entry barrier for sustainable fabrication by systematically exploring the use of biomaterials and compliant fabrication processes to create new artifacts. Our work tackles this issue from a multi-disciplinary perspective and focuses on two key aspects: the materiality and the processes.

First, as functional prototyping plays a significant role in designing interactive artifacts in the field of HCI, we import and render accessible knowledge from material science to propose material formulations that widen the spectrum of functional properties of bioplastics. We demonstrate the use of functionalized bioplastics as a more sustainable approach to realizing soft devices [1] (UIST'22) and deformable shape-changing interfaces [2] (DIS'24). Second, we explore the inherent capability of biological systems to generate intricate materials and investigate how their biological can be leveraged as fabrication and electronics embedding processes. We demonstrate Biohybrid devices [3] (UIST'23) a new class of computing devices that we call Biohybrid. These devices combine bacterial cellulose, a bio-based material produced by living organisms acting as a substrate, with conventional electronics for real-time interaction. Through this demonstration, we aim to showcase the potential of prototyping with biomaterials as a more sustainable practice and shed light on new avenues for research, design, and making.

2 Biomaterials for HCI

2.1 Creating sustainable input and output interfaces using accessible biopolymers

We address the question of materiality by enabling the creation of sustainable input and output interfaces using accessible conductive and functional biomaterials.

Interactive Bioplastics [1], is a fabrication framework that focuses on the conductivity of bioplastics and presents an accessible end-to-end approach for DIY fabrication of electrically functional soft interactive devices from low-cost bio-based and bio-degradable materials. In this work, we introduce three types of carbon-infused bioplastic materials–conductive sheets, pastes, and foams– that can be shaped with classic digital fabrication techniques and combined with conventional electronics to create fully functional devices. Examples of such devices include on-body circuits, capacitive touch sensors, skin-exposed EMG electrodes, and a self-contained computing device that can be disassembled and re-molten (Fig. 2 A).

Next, **SoftBioMorph** [2] focuses on functionalizing several other properties, such as elasticity, water resistance, water absorption, etc, to widen the spectrum of shape-changing behaviors for mechanical output. It introduces accessible synthesis, assembling, and interfacing techniques that allow achieving three primitive types of topologically equivalent shape-change: volume, orientation, and form that we illustrate through five application cases (Fig.2 B).

The demonstrated applications show how bioplastics can substitute conventional substrates and conductive prototyping materials. By opening up a space for prototyping input and output interfaces with bioplastics and empowering makers with accessible fabrication techniques, these frameworks can act as valuable starting points for sustainable prototyping and further design space exploration, thereby creating new interaction opportunities.

2.2 Creating biohybrid devices using growing materials

We question conventional fabrication processes by proposing biohybrid devices [2], a new class of interactive devices that merge biological and digital fabrication processes to grow interfaces that embed electronics at all stages of the material's life-cycle. These devices combine bacterial cellulose (acting as a substrate) with electronics (for real-time interaction). We explore the inherent capability of biological systems to generate intricate biopolymers and investigate how they can be leveraged beyond classic product design. We propose a radically different fabrication framework centered on the biomaterials' life cycle phases in our contribution. We introduce novel fabrication techniques for electronics embedding at each lifecycle phase (Growth, Stabilization, and Inanimate). We demonstrate fully functional Biohybrid Devices that showcase different inputs and outputs, including flexible deformation sensors, planar and curved multi-touch sensors, visual displays, and mechanical actuators (Fig. 2 C). While our fabrication framework focuses on bacterial cellulose, it is a new, realistic perspective for prototyping interactive devices that can be applicable today in a DIY setup and extended to other living organisms in future research.

3 Interactivity

During the demo session, we will present various prototypes, including electrically conductive and interactive bioplastics, shape-changing bioplastics and biohybrid devices made out of Bacterial Cellulose, but also our physical library of bioplastics samples and Bacterial Cellulose samples from all lifecycle phases. The audience will be able to touch and manipulate the raw materials as well as interact with the functional devices. A screen will display the videos of the respective projects.

Through this demo, we aim to inspire designers and makers to create more design spaces where sustainability and functionality co-exist and take advantage of each other. Thus, we encourage the audience to question, reflect, and engage in discussions about the role of technology in shaping our world.

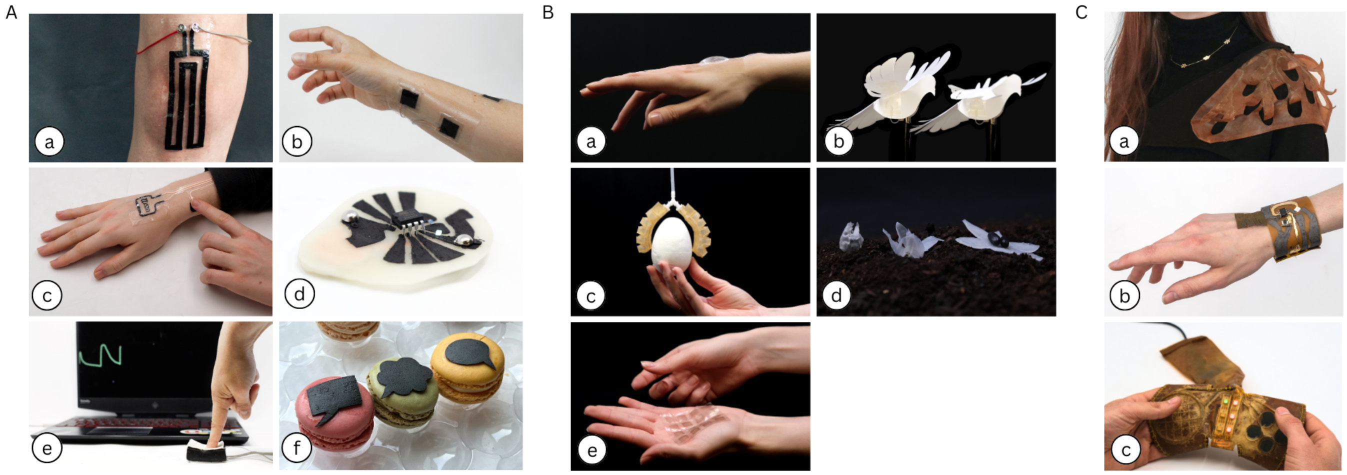

Figure 2: Different devices illustrating the potential of bioplastics and bacterial cellulose as prototyping materials. A : Interactive Bioplastics uses bioplastics substrates and semi-conductors for on-skin applications such as (a) stretching sensors, (b) EMG electrodes, (c) circuits featuring classic LEDs and off-skin applications such as (d) stand-alone circuit board, (e) pressure sensors and (e) capacitive macarons. B : Soft Biomorph uses bioplastics as prototyping materials for shape-changing applications such as (a) epidermal inflatable interfaces, (b and c) bending actuators, (d) environmentally-actuated interfaces and (e) auxetic materials. C : Biohybrid Devices uses bacterial cellulose to biologycally grow multimodal interfaces such as (a) a shape changing wearable shoulder pad, (b) a wearable interactive bracelet and (c) a deformable game controller.

References

[1] Marion Koelle, Madalina Nicolae, Aditya Shekhar Nittala, Marc Teyssier, and Jürgen Steimle. 2022. Prototyping Soft Devices with Interactive Bioplastics. In *Proceedings of the 35th Annual ACM Symposium on User Interface Software and Technology* (Bend, OR, USA) *(UIST '22)*. Association for Computing Machinery, New York, NY, USA, Article 19, 16 pages. https://doi.org/10.1145/3526113.3545623

[2] Madalina Nicolae, Claire Lefez, Anne Roudaut, Samuel Huron, Jürgen Steimle, and Marc Teyssier. 2024. SoftBioMorph: Fabricating Sustainable Shape-changing Interfaces using Soft Biopolymers. In *Proceedings of the 2024 ACM Designing Interactive Systems Conference* (IT University of Copenhagen, Denmark) *(DIS '24)*. Association for Computing Machinery, New York, NY, USA, 496–508. https://doi.org/10.1145/3643834.3661610

[3] Madalina Nicolae, Vivien Roussel, Marion Koelle, Samuel Huron, Jürgen Steimle, and Marc Teyssier. 2023. Biohybrid Devices: Prototyping Interactive Devices with Growable Materials. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology* (San Francisco, CA, USA) *(UIST '23)*. Association for Computing Machinery, New York, NY, USA, Article 31, 15 pages. https://doi.org/10.1145/3586183.3606774