

# Demo: From Plastic to Biomaterials: Prototyping DIY Electronics with Mycelium

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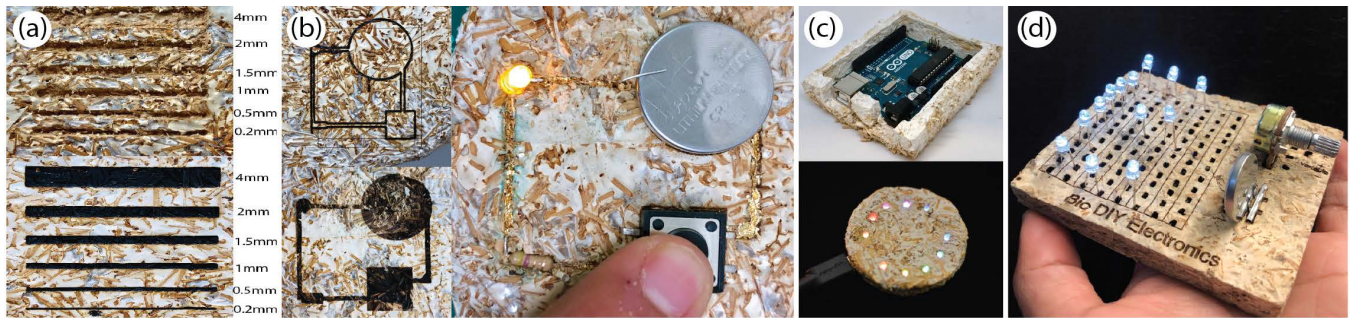


Figure 1: (a) CNC carving and Laser engraving tests. (b) Mycelium for embedding electronics. (c) Mycelium as an enclosure for electronics (Arduino UNO and Circuit Playground) (d) Mycelium as an electronic component (Bio-breadboard).

## ABSTRACT

Researchers, makers and hobbyists rely on plastics for creating their DIY electronics. Enclosures, battery holders, buttons and wires are used in most of the prototypes in a temporal way, generating waste. This research aims to extend the boundaries of biomaterials applications into electronics. Mycelium is a fast-growing vegetative part of a fungus which adapts to different shapes when growing in a mold and decomposes after 90 days in a natural environment as organic waste. In order to create more sustainable prototypes, we use mycelium composites with common digital fabrication techniques for replacing plastic in electronics. We present our method for growing mycelium, our design process of using digital fabrication techniques with mycelium, applications for embedding electronics in mycelium boards, making enclosures for electronics, and using mycelium within electronics. This paper could contribute with the merge of biomaterials and electronics, an approach which is still under exploration.

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## CCS CONCEPTS

• **Human-centered computing** → **Interface design prototyping**; *Haptic devices*.

## KEYWORDS

biomaterials, mycelium, electronics; digital fabrication; bio fabrication; rapid prototyping, DIY electronics.

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## 1 INTRODUCTION

The use of biological materials as main components in design has been explored in the field of Biological Human Computer Interaction [16]. Current research labs or maker spaces do not have a recycling process and reuse several materials used for making their DIY projects, instead waste is generated along the prototyping process, fails and iterations. Bio-materials offer a more sustainable alternative to waste due to their biodegradable properties. There are some approaches in applying DIY tools for biomaking [4], however it was not proposed to merge biomaterials with electronics. In order to select the biodegradable material that could be more

appropriate for this project, we compare the physical properties between the most common biomaterials to envision its application in DIY Electronics (Tab. 1). We realized mycelium is more suitable for DIY electronics applications due to it is heat resistant, thermal resistant, light weight, shapeable, hydrophobic, and it has degree of strength depending on the substrate it is growing [8]. The mycelium growth is only part of a mushroom life-cycle because there are no mushroom spores or fruiting bodies involved in this process [1]. Furthermore, using mycelium-based biomaterials for making electronics' enclosures, embedding circuits and creating DIY electronics aid by digital fabrication techniques, are an alternative to replace common materials used for DIY prototypes such as acrylic, vinyl, wood and plastic.

**Table 1: Physical properties: comparison between different types of biomaterials [3], [6], [14], [17],[8].**

Property	SCOBY	Algae	Bioplastic	Mycelium
Degree of strength	Yes	Yes	Yes	Yes
Shapeable in real time	No	Yes	Yes	Yes
Thermal Resistant	No	No	No	Yes
Heat Resistant	Yes	No	Yes	Yes
Light weight	Yes	Yes	Yes	Yes
Hydrophobic	No	Yes	Yes	Yes
Compostable	Yes	Yes	Yes	Yes

## 2 RELATED WORK

Mycelium-based products have been manufactured in a diverse range of potential applications including acoustic dampers, paper, textiles, bricks, foams (for packaging, and medical applications), and even for vehicles and electronic parts [8]. However, most of the companies that have created these various mycelium-based products keep the technology and processes they use as a trade secret protected by their patents, including the specific strain they use [10].

Start-ups and several companies have been creating different mycelium-based products. Ecovative [5] have pioneered the idea of using mushroom-based foam. Moreover, Dell decided to use mushroom materials in its packing cases under the eco-friendly fungi foam name [1]. MycoWorks [13] developed a mycelium-based bricks that could replace common construction materials. MOGU [12] is currently developing solutions such as resilient flooring, thermal and acoustic insulation panelling, decorative elements and furniture components. This company has also developed mycelium-like leather and it is one of the few that describes part of its mycelium growing process. Moreover, artists and designers are also including these products in their creations. Aniela Hoitink and Myco Design Lab created MycoTex, a dress made only from mycelium discs [15]. MycoTecture [2] designed an architectural installation with fungus blocks.

## 3 PROTOTYPING DIY ELECTRONICS WITH MYCELIUM

Mycelium presents great attributes for intertwining it with electronics. We used an already commercialized 'Grow-It-Yourself' Mushroom Material [7] which comes in a bag, to start pushing the boundaries of the mycelium-based design. After we grew molded shapes with various thicknesses necessary for this research project, we used digital fabrication techniques for DIY electronics implementation. Due to the different recipes for growing and fabricating the mycelium-based products, they could be created with different densities and weight.



**Figure 2: GIY bag and growing mycelium process.**  
Photo: CC0 Ecovative Design.

**Biofabrication: Growing Mycelium.** First, we sterilized the work area, measuring spoons and kitchen scales using alcohol. Second, we added flour and water in the bag and follow all the instructions for mycelium activation which are specified in the bag [7], and we stored it in a dark area for about 4-6 days at a room temperature (27°C or 80°F). After that time, the substrate will turn into a white color which means the mycelium colonization was successful. Third, we transferred the amount of material needed into a mold. The mycelium material can grow into any shape or design. After this step, we covered the mold with a bioplastic film and make some cuts in the surface to enable the mycelium to breath. After all, we put the mold in a dark area for about 4-6 days until it becomes white again. Finally, we took the grown parts out of their molds and put them into the oven (80°C or 194°F) to stop the growing life cycle. This step is basically to kill the mycelium and to obtain a final bio product. In summary, the growing process takes about 12-20 days since the mycelium activation in the bag to the time when the myco-composite piece is ready to use. This is a sample of a mycelium growing process (Fig.2).

**Digital Fabrication.** This research project compared the three most common digital fabrication techniques using mycelium: 3D Printing, Laser Cutting and CNC Carving [11]. We tested these techniques on the mycelium pieces in order to open a new canvas for making DIY electronics. The CNC carving and laser etching tests show the material behavior under these techniques (Fig.1a). We also explored engraving a circuit and laser cutting some shapes for embedding electronics on the bio-board. We found that CNC carving is not



the best technique for making electronic circuits because the default material on the bag (hemp) is rough. However, this technique can be used for carving larger areas for embedding electronics. We used this technique for embedding a coin battery into the composite material, then we traced a circuit and filled it with metal leaf to have a conductive surface of an LED circuit. Our last test, was filling the traced circuit with gallium in its liquid state to create a switch which turns on an LED. The line thickness in both tests was 3 mm., which worked the best with the CNC carving technique (Fig.3).

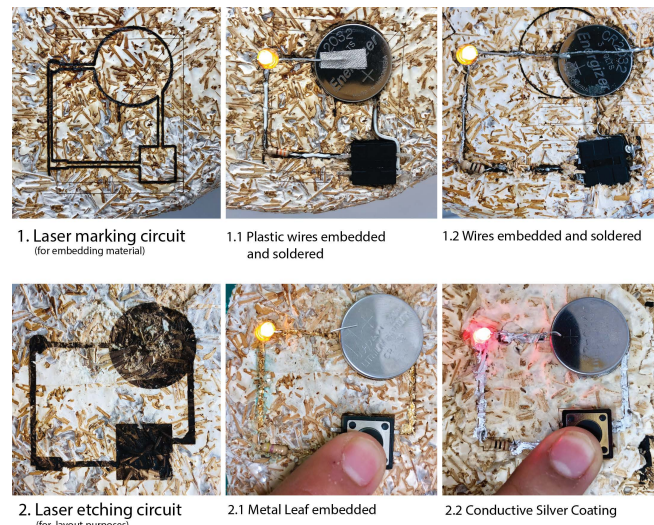


**Figure 3: Design 1: Coin battery embedded in mycelium. Design 2: Gallium used on a myco-composite circuit.**

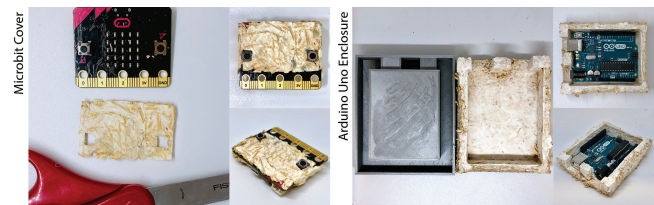
**Mycelium for Embedding Electronics.** The laser cutting and engraving technique let us have a circuit layout reference on the biomaterial surface in order to embed electronics after. We used 4 different materials for creating the circuit: cable covered with plastic, metal leaf, conductive silver coating and wires (Fig.1b), (Fig.4). After testing these 4 materials, we realized that the first 3 conductive materials are more useful for electronics approach: cable covered with plastic which has to be soldered to the components, metal leaf which was embedded in the circuit paths by pressure, and finally conductive silver coating which is highly recommended due to its high conductivity when it's completely dry. The wires didn't work well because it kept popping out the circuit path and the conductivity was unstable. The circuit line thickness was 2 mm.

**Mycelium as Enclosure for Electronics.** We created enclosures for DIY electronics such as microcontrollers, which are commonly used in makerspaces or research labs (arduino UNO, micro bit, and circuit playground). We 3D printed a negative 3D model to be used as a mold for the arduino UNO (Fig.1c), (Fig.5). As part of the exploration, other mold shapes were used in order to have homogeneous pieces of 15mm (0.5inch) thickness, the ones we used to make our electronic circuits tests.

**Mycelium as an electronic component.** We made a breadboard out of mycelium material. This electronic component size is 76mm.x51mm. (3"x2") and it allowed us to replace the common plastic breadboard by a compostable one. The bio breadboard was successfully developed and we incorporated a connection in the circuit for a battery



**Figure 4: Laser cutting and CNC machining tests in the mycelium-composite material for tracing circuits.**

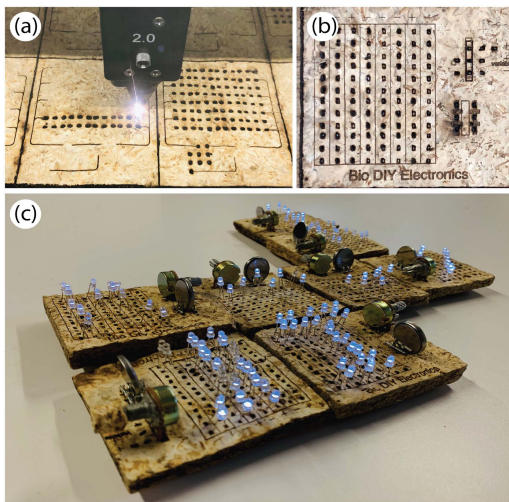


**Figure 5: Microbit and Arduino Uno enclosure.**

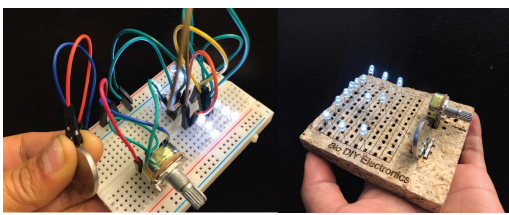
holder and a potentiometer to offer interaction to the user (Fig.1d). The bio-breadboard was laser cut and some etching was made on both sides of it for design purposes (Fig.6a, 6b). Finally, wires were used on the back of the bio-breadboard following the designed circuit to enable conductivity on it. For testing, we added some LEDs to interact with them by making a composition (Fig.6c). We also made a comparison between how a circuit looks like in a common breadboard and in our proposed bio-breadboard (Fig. 7).

#### 4 DISCUSSION

The use of biomaterials provide many advantages to product design field because they are made from natural renewable resources, can be recycled, reused, or composted. Thus, they are an excellent alternative to waste (failures and unused prototypes) that now can be 100% biodegradable. We decided to use mycelium because of its suitable properties for DIY electronics applications (heat resistant, thermal resistant, light weight, degree of strength, shapeable and hydrophobic). Furthermore, this biomaterial decomposes in nature in less than 90 days as any other organic waste. Common prototyping materials such as PLA, acrylic, or FDM can remain in the



**Figure 6: Biocompostable breadboard, making process.**



**Figure 7: Circuit in a Plastic breadboard vs. Bio-breadboard.**

landfill for hundreds of years as any other piece of plastic if they are not disposed under the right conditions [9]. Even though mycelium-composite shows an alternative to plastic in prototypes, it still has limitations in strength and further physical test should be made to become a long-lasting material. However, it is a great alternative material to use in the iteration process of product design such as enclosures for electronics, or chassis for embedding motors or any others electronic components.

## 5 CONCLUSION

Prototyping materials are mainly based of plastic such as acrylic or they contain a toxic resin in its composition such as FDM. Using mycelium as a bio-composite material for DIY electronics opens novel possibilities for replacing those non-ecofriendly materials and making our practice, as researchers, designers, makers or hobbyists, more sustainable. We envision its application to biodegrade enclosures and reuse the electronic components in future projects, biodegrade failures in the digital fabrication process and biodegrade material that remains and is not used after laser cutting. This project presented our process for growing our own biodegradable material in different scenarios: to make buttons for switches

or keyboards, to create enclosures for electronics, to prototype in bio-breadboards instead of plastic ones, and to engrave and embed electronics. Future work will explore other biodegradable materials to replace other plastic-based and conductive materials, to conduct physical tests such as tensile, strength, biodegradation time, heat resistance and compostability.

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