Engaging with the making and the end-of-life of artificial interactive nails

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CCS Concepts

• **Human-centered computing → Interaction design process and methods**.

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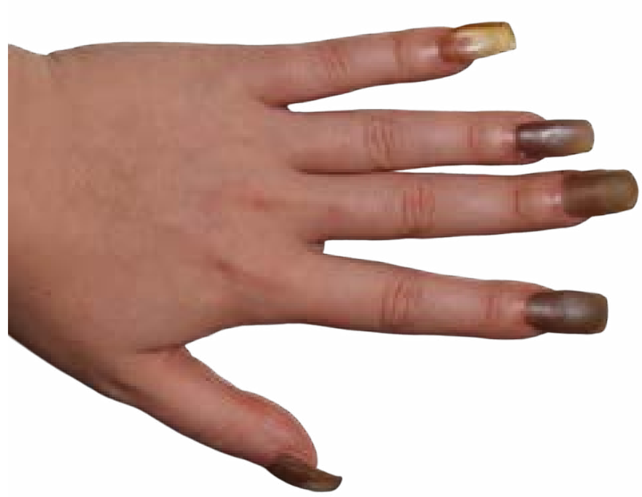

Figure 1: We experimented with the formula of the Bio-e-Nails to show variations in shape and opacity.

1 Introduction

As wearable technology has seamlessly become an integral part of our daily lives, HCI research continues to provide innovative solutions that intersect multiple disciplines [23, 24].

Significant effort has been made toward developing devices such as smartwatches [1, 46, 56], earbuds [27, 42], and armbands [40] that enable individuals to monitor their health, ensuring hands-free communication and streamlined notifications for safety.

Beyond these efforts, wearable technology has expanded its applications to include fashion items worn daily, such as rings [3], shoes [2, 45], and jackets [16]. A more recent trend includes fashion items worn for aesthetic enhancements, such as artificial nails, eyelashes, hair, and makeup, collectively referred to as beauty technology [53].

Beauty technology encompasses the body of work that augments everyday cosmetics by adding features supported by electronics [51, 53]. Thus, besides the typical motivations for cosmetic use, such as beautification or altering appearances, beauty technology adds features by utilizing electronics.

FX e-makeup [50], for example, is a prototype for special effects makeup embedded with electronics to sense and use facial muscle movements as inputs for performing commands (e.g., turning on a TV). iSkin [54] is an on-the-skin tattoo-like interface combining aesthetically appealing designs with electronics that utilize touch as input.

Similarly to fast fashion, beauty technology presents sustainability challenges influenced by factors such as material composition, production processes, and end-of-life disposal, with the added caveat of e-waste [22].

For instance, wearables for beauty technology integrate electronics or conductive coatings [53], posing difficulties for proper recycling due to the challenges of separating electronic components from off-the-shelf cosmetics [22].

Concerned with sustainability, recent Human-Computer Interaction (HCI) research shows a growing interest in biobased materials, such as mycelium skin [49], mycelium composites [32, 48, 55], bioplastics [8, 29, 58], biofoams [30, 31], bioclays [14, 17, 19, 41], and bacterial cellulose [10, 20, 36].

This interest is driven by the ability of these materials to break down in a home-compostable environment, enabling the reuse or reharvest of electronic components at the end of the wearable or interactive artifact's life.

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2 Bio-e-Nails

We designed these artificial nails, which we call Bio-e-Nails, with a sustainable approach using biobased materials. While the Bio-e-Nails can be attached to the human nail and worn similarly to their plastic counterparts (Figure 2), we differentiate in the choice of material, and in the making process.

We chose to formulate the material ourselves, from raw ingredients that were biologically derived, such as agar (originating from algae) and chitosan (originating from insects crust). Thus, our making has been intimate [14] and includes biodegradable plastics, such as Alganyl [8], which can be easily tuned for strength and flexibility. These materials decompose in soil, and completely disappear in chemical solvents. We experimented with a hands-on process, went through hundreds of iteration and engaged with various raw ingredients.

The unlocked freedom of customization allowed us to explore color variation, manipulation of bioplastic layers, and use of embellishments. As a result, the Bio-e-Nails ranged from purely aesthetical, to interactive wearables embedding photo and thermochromic pigments and NFC chips.

In our process, we chose to intersect the material-driven design [18, 43] and intimate making [14] approaches, willing to actively listen to and learn about the material, rather than rely on our own expertise. With each new nail, we used touch, sight, and feel to get informed about the following steps: whether we needed more rigidity in the material, a smoother texture, a more vibrant color, or more dramatic length and curvature.

As we delved deeper in the biochemistry of the materials, we expanded our understanding of where these nails, as extension of our bodies, should end. We dedicated a lot of time to the making of the nails. Similarly, we strove to give equal attention to their end-of-life, focusing on their re-use and on creative mechanisms for their decomposition.

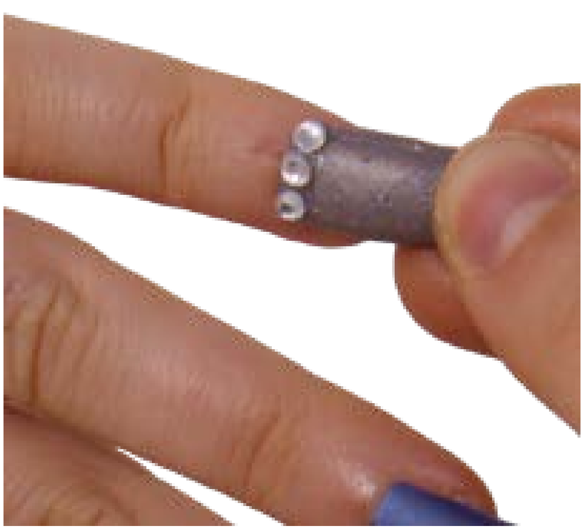

Figure 2: The Bio-e-Nails can worn like regular plastic nails.

We then experimented with adding functionality to the Bio-e-nails by embedding NFC (near field communication) chips. By doing so, we tapped into a previously explored area within HCI, that is of hands-free interactions meant to cover situations where the typical finger-based gestures such as tapping or swiping may be inaccessible due to impairment [57], distractions-induced risks [25], or while mobile [21, 44].

Figure 3: The Bio-e-Nails embed an NFC chip that can be programmed to turn on the phone flashlight.

Prior research has shown that by embedding electronics, such as Radio Frequency Identification (RFID) chips, in artificial nails, interactions with mobile phones can become swift and seamless [33, 34, 52]. However, these past works have used off-the-shelf materials such as acrylic nails or stickers [26, 52] as substrates for the electronic components, thus creating a composite material that is hard to recycle or biodegrade, raising sustainability concerns. Building upon prior research, we explore the affordances of biodegradable materials that provide an ideal landscape for designing and fabricating temporary wearables, such as smart artificial nails, typically intended as *non-permanent* beauty enhancements.

We engaged directly with our Bio-e-Nails, by wearing them daily for one week during which we programmed them to trigger specific functions on the phone with a quick and discrete tap. Aligning with prior research, we focused on scenarios where ob- taining assistance can be critical and usual gestures are unavailable. Thus, we programmed the bio-e-nails to perform three functions: (1) navigate to a predefined location while driving, (2) discreetly call for help when in danger, and (3) automatically text the current location to a friend.

The Bio-e-Nails presented in this work illustrate our commitment to fostering sustainability in beauty technology by exploring diverse biomaterial affordances beyond biodegradability. The affordances we consider in our approach include low-tech fabrication, customization, and flexibility in design. Our nail-based interactions showcase their potential, especially when traditional gestures may be impractical or unavailable during critical moments.

We envision the exhibition visitors to engage with our Bio-e-Nails either by using a provided UV pen to excited the photochromic pigments or by interacting with the NFC chips embedded in the nails.

Figure 4: Our interdisciplinary approach enables the exploration of multiple methods for the end-of-life of the Bio-e-Nails. The mechanical method involves separating the layers and puling out the electronics. The chemical method dissolves the substrate bio-material in water or vinegar. The biological method decomposes the biomaterial substrate in a soil mixture containing micro-organisms. These methods can be combined for a more effective degradation.

3 Sustainability Aspects

Leveraging the interdisciplinary nature of our project, we explored various approaches that offer a sustainable end-of-life to the Bio-e-Nails.

Re-use is one of the sustainable end-of-life options that is often overlooked in favor of recycling or composting. While more cumbersome, re-using limits disposal and uses more efficiently the materials. During this project, we iterated through hundreds of nails, some of which did not lend the intended aesthetic and functional properties (Figure 5). We experimented re-using those nails by leveraging their chemical end-of-life option. While experimenting, we realized that re-use we can enable wider aesthetic explorations, such as embedding artistic thermochromic and photochromic pigments, which otherwise would not be considered sustainable since their chemical composition is not disclosed by the production companies. Thus, using small amounts of vinegar as a solvent (just enough to cover the nail), we heat the thermochromic nail in the microwave for 1 minute and then pour it back into the clay mold. After curing, we obtained a new nail that kept the thermochromic properties but was thinner and more transparent than the original (due to the added solvent) – we obtained a thicker result when we re-used the material for a smaller nail.

Figure 5: The intermediate versions, considered failure from an aesthetic and functional perspectives, were re-used to create new nails. This was possible because we chose a biomaterial that can be reversed from solid to fluid state by adding water and heating them in the microwave.

End-of-life: mechanical. Our proposed fabrication process, based on thermo-adhesion enables easy separation of the bioplastic layers, simply by using manual mechanical force. We successfully harvested and re-programmed the NFC chips. The remainder of the bioplastic can be melted down, cured, and re-shaped into a new bioplastic layer (see Figure 4).

End-of-life: chemical. We leveraged the water-solubility of the bioplastic at low temperatures (<50 °C), to successfully recover and reprogram the NFC chips. When using small amounts of water (20 mL), the solution containing the dissolved bioplastic can be brought to boil and poured into a new bioplastic layer (see Figure 4).

End-of-life: biological. Alternatively, our Bio-e-Nails can decompose in soil over time. Our experiments show a slow mass loss (10% over 10 days) in soil inoculated with bacteria and fungus and kept at 40°C and over 80% humidity (see Figure 4).

4 Installation

We envision an installation encased in a suitcase as depicted in the Figure 6. The installation will capture aspects of the *fabrication process*, from the molding, pouring, filing and embedding the NFC chips. We will showcase various iterations of the nails, including intermediate versions. We plan to show other aspects of the fabrication such as some of the tools used (in Figure 7 we show the exact nail filer we used in the process).

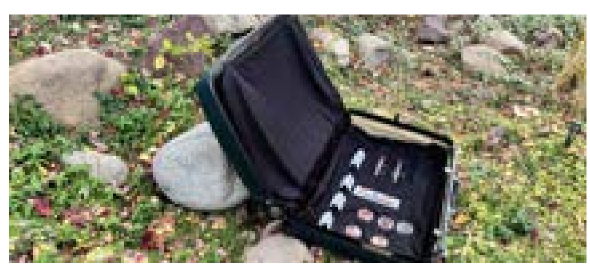

Figure 6: We envision the installation in a suitcase.

The finalized Bio-e-nails shown on the right side of Figure 7 are *interactive*. As shown in Figure 8, the exhibition participants will be able to use a UV pen to interact with the photochromic pigments embedded in the nails, and thus trigger their color change

Figure 7: The installation will showcase the process, as well as various intermediate nails. The exhibition participants will have the option to interact with the final Bio-e-Nails.

in real time. Using their phones, the exhibition participants will be able to interact with the NFC chips programmed to link to the page revealing more information about the project. Last, we plan to embroider the artist statement in the textile that will become the background of the installation. The artist statement will capture our positioning as well as our vision.

Figure 8: An ultra-violet (UV) pen is exciting the photochromic pigments in the nails. As a result the nail change colors from pink to dark purple. The change lasts for an amount of time proportional to the UV exposure. Inside, the effect is temporary and the nails regain their original color within seconds. When worn outside, the color change can last longer depending on the sun UV intensity.

5 Participating Artists

Mirela Alistar is a bioartist, HCI researcher, and an Assistant Professor in Soft Materials at ATLAS Institute, University of Colorado Boulder, USA. Intersecting microbiology and HCI, her work extends the human to include interactions with their own microbiome and other living organisms [5, 11–15, 31, 37]. She has developed tangible living-media interfaces [28, 35, 39], and biochip-based systems for personalized healthcare [4, 6, 7, 38]. She has extensive experience organizing workshops in the context of DIYBio labs that she led or co-funded. In the academic context, her research attracts significant interest in the HCI research community: the workshop on bioplastics that she co-organized for TEI'22 [9] had over 50 participants.

Shirp David is a graduate student researching regenerative and compostable materials. With a background in fashion studies in Philadelphia, Shirp is fascinated by the collaboration between nature and science. Exploring fungal and bacteria materials as textiles or building components, Shirp identifies as a designer and architect, and definitely as an alchemist, humanist, and craftsman.

Eldy Vasquez Lazaro is a Peruvian designer with an MFA in design from University of California Davis and a B. Arch. from San Pedro University in Peru. Prior to joining CU Boulder, she was a resident at Autodesk Technology Center in San Francisco where she researched the use of mycelium bio-composites for applications in product design and wearable technology using digital fabrication techniques. She is currently a doctoral student at the ATLAS Institute of CU Boulder researching across the Unstable Design Lab and Living Matter Lab. Eldy's research interests include the use of compostable conductive materials for creating tangible interfaces and wearable technologies while addressing challenges in sustainability [30–32, 47–49].

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