ChromaNails: Re-Programmable Multi-Colored High-Resolution On-Body Interfaces using Photochromic Nail Polish

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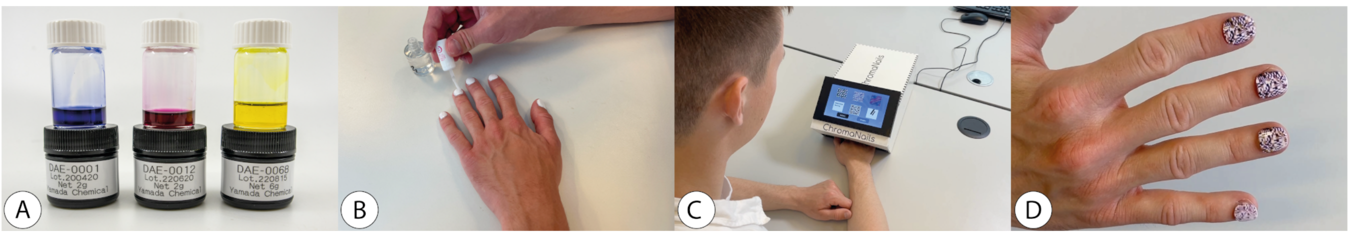

Figure 1: We can create re-programmable multi-colored textures from photochromic nail polish. (A) We mixed CMY photochromic dyes together with transparent nail polish to create a multi color mixture. (B) User applies the nail polish on top of a white nail polish. (C) The ChromaNails Re-programmer is used to program the nail polish to achieve (D) high-resolution multi-colored textures on nails, that can be re-programmed multiple times.

ABSTRACT

We demonstrate ChromaNails, a physical nail reprogramming device that enables high-resolution multi-color textures on fingernails using photochromic nail polish for on-body interaction. Our ChromaNails reprogrammer uses a miniature RGB projector and a UV light source to project different wavelengths of light onto our photochromic nail polish. We create this nail polish by mixing cyan, magenta, and yellow (CMY) photochromic dye into a base substrate polish. This enables us to control the saturation and desaturation of the CMY particles inside our nail polish to various colors inside the CMY color space. Our integrated user interface enables laypeople to select their preferred color texture and adapts to various nail shapes. We demonstrate the usefulness of ChromaNails for on-body interaction through four application examples on reprogrammable fingernail QR codes, on-body calendars, security, and fashion.

CCS CONCEPTS

• **Human computer interaction → Human computer interaction (HCI)**.

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KEYWORDS

on-body interfaces, photochromic, multi-color textures, color change, nails, fingernails

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1 INTRODUCTION

In Mark Weiser's vision of the future[9], computing seamlessly integrates into our everyday lives, becoming ubiquitous and unobtrusive. One promising surface for such an interactive paradigm is the body itself. There has been extensive research on on-body interfaces exploring the human skin [4, 6, 11] and hair [1], as they hold the potential for direct natural interaction as our body is permanently accessible to interact with ubiquitous information.

Research within HCI has shown increasing interest in nails as an interactive digital medium. Researchers demonstrated the potential of interactive nails by integrating sensing through capacitive touch [5], or RFID-tags [8], while others researchers focused on integrating displays with e-ink[2], or small OLED screens [7]. However, most of these technologies rely on bulky and complex electronics that are difficult to unobtrusively house on a nail. To address this, we present a photochromic nail polish that is thin and does not require any electronics on the nail enabling re-programmable high-resolution multi-colored textures on nails.

Photochromic particles are capable of changing color saturation between transparent and saturated when exposed to different wavelengths of light. Ultraviolet (UV) light saturates the particles, and visible light desaturates them, allowing them to take on partial states through saturation and desaturation. This process is fully reversible and can be repeated multiple times.

Recent research [3, 10] introduces a cyan, magenta, and yellow (CMY) mixture of photochromic particles that utilizes the different wavelengths that desaturate the individual dyes to create high-resolution multi-colored visual textures on objects and textiles[3, 10]. However, using this re-programmable material for on-body interfaces has not been explored yet.

In this demonstration, we present ChromaNails, a re-programming device that generates high-resolution multi-color textures on CMY photochromic nail polish using a miniature RGB projector and UV lights. Our integrated user interface enables laypeople to select a color texture, place them on individual fingers, preview the end result before applying, and finally reprogramming a finger nail with our system. Our UI also takes into account different nail curvatures. An integrated camera lets users see and relocate the individual textures on their fingers in real time before reprogramming. We also contribute the fabrication of the photochromic nail polish and detail the mix ratio of cyan, magenta, and yellow photochromic dye into a commercially available clear nail polish. We demonstrate four application examples: QR-codes for mobile information sharing, security access keys, on-body notifications, and fashion.

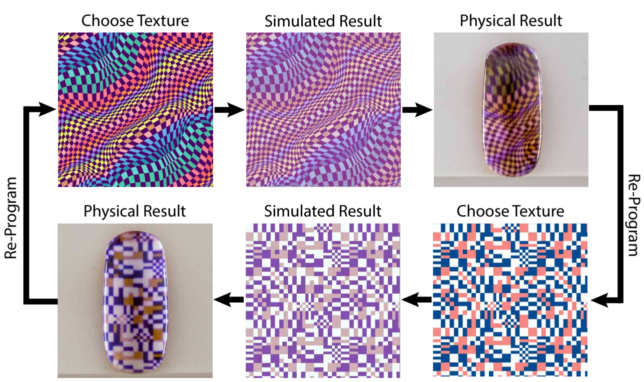

Figure 2: The Re-programming Process

2 CHROMANAILS

The ChromaNails reprogrammer (Figure 3) generates high-resolution multi-colored visual textures on photochromic nail polish using a modified RGB projector and UV lights. We detail the nail polish mixture, the mechanical design of ChromaNails, the optimization system for computing the projection and our user interface.

2.1 Nail Polish

By combining Manhattan transparent nail polish[1] (Figure 4B) with P-type photochromic dyes (Yamada Chemical Co.) 0.1wt% cyan

[1]Top coat https://www.manhattan.de/de-de/nagel/top-coat/top-coat/

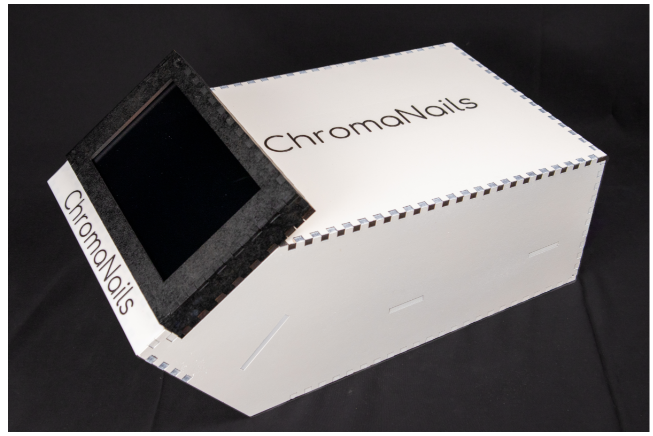

Figure 3: ChromaNails reprogrammer

(DAE-0001), 0.1wt% magenta (DAE-0012) and 0.4wt% yellow (DAE-0068), see figure 4A, we create a CMY photochromic mixture (Figure 4C).

Initially we used the CMY ratio from Photo-Chromeleon [3]. However, we noticed that the yellow dye desaturated notably faster compared to cyan and magenta within our nail polish substrate. To address that, we increased the amount of yellow dye to 0.4wt%, which gives a longer desaturation time but simultaneously made the mixture have a yellow tone when fully saturated. However, since the yellow desaturates fast, we compensate for its increase it in our computational model. Due to the fact that the fully desaturated state is transparent, we apply a white base coat[2] underneath the photochromic nail polish to achieve white.

Figure 4: The Photochromic Mixture. (A) cyan, magenta and yellow photochromic dyes, individually mixed with transparent nail polish. (B) Transparent nail polish. (C) Fully saturated mixture of transparent nail polish and CMY dyes.

2.2 Hardware

The ChromaNails reprogrammer has the following components: a Nebula Solar Portable RGB Projector[3], two Alonefire 10W 365nm UV lights[4], one Raspberry PI 4 8GB Ram[5], one DFRobot Raspberry

[2]White Nail Coat Polish Depend O2 A031, https://dependcosmetic.dk/vare/o2-basic-34/
[3]Nebula Soloar Portable projector https://us.seenebula.com/products/d2131
[4]Alonefire 365nm UV Flashlight https://www.amazon.com/Alonefire-Flashlight-Portable-Rechargeable-Blacklight/dp/B07SWW5FHB
[5]Raspberry Pi 4 Model B 8GB Ram https://www.raspberrypi.com/products/raspberry-pi-4-model-b/

Pi LCD 7-inch Touchscreen[6], and one 8-MP Raspberry Pi Camera Module 2[7], see figure 5.

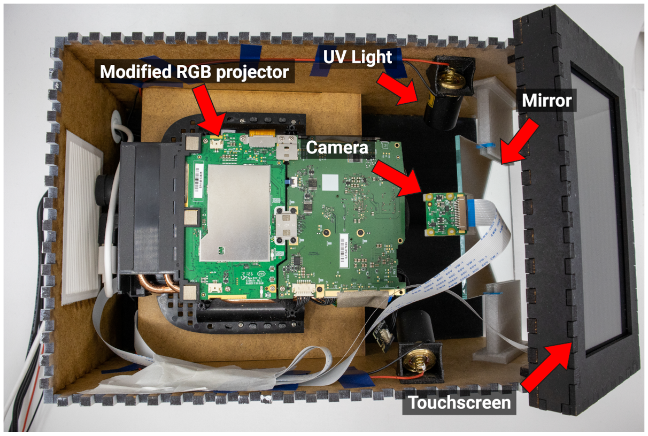

Figure 5: ChromaNails the physical prototype

We modified the RGB Projector with an Everix ultra-thin 535 nm bandpass filter[8] to narrow the wavelength spectrum of the green LED, such that each LED's light spectrum matches with the absorption peak of one of the dyes. The blue LED matches with the yellow dyes absorption peak, the green LED with magenta and red LED with cyan, see figure 6. A matching emission spectrum and dye absorption spectrums yields an efficient desaturation of the corresponding dye.

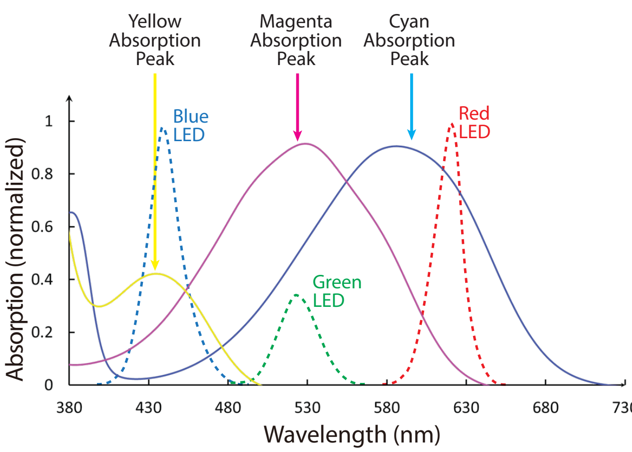

Figure 6: Absorption peak of each dye and our RGB projector emission spectrum

The Raspberry Pi runs the projector, UV light circuit, touchscreen UI, and the reprogramming process. This includes the illumination times of each RGB led for each pixel on the projector. The camera is integrated to provide users with visual feedback, facilitating precise image placement on their nails using the touchscreen.

2.3 Software

The photochromic dyes used in the nail polish mixture have overlapping desaturation curves but individual absorption peaks in which they desaturate the most. Therefore, we have to take the desaturation times of all dyes into account, when shining red, green, and blue (RGB) light on the photochromic coating. To do this, we evaluated the desaturation effect that each RGB light has on each photochromic dye with the same experimental setup as in Photo-Chromeleon [3], see figure 7.

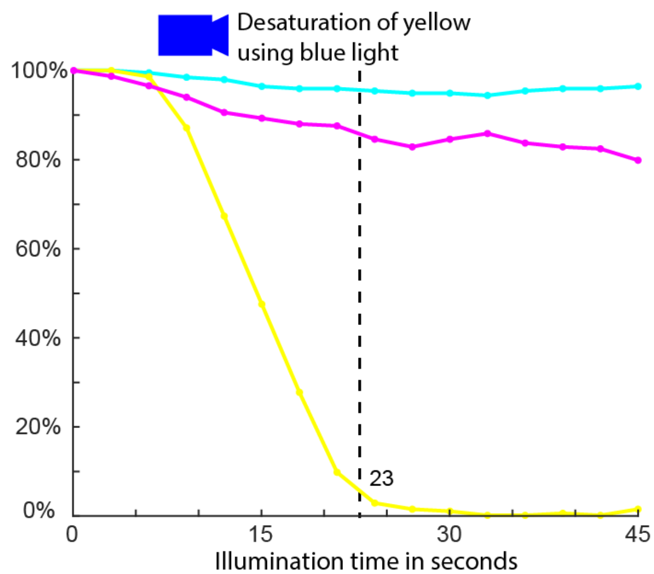

Figure 7: Blue light effect on the photochromic dyes

We integrated the new desaturation data into the optimization algorithm from Photo-Chromeleon [3]. The algorithm finds the closest approximation of our target color and outputs the illumination times to achieve them. We use the illumination times to simulate the physical results and to reprogram the photochromic coating on the nails using the RGB projector.

The user interface on the touch screen located on the front of the ChromaNails reprogrammer allows users to choose a texture they would like on one or multiple of their fingers (Figure 8A). It simulates the expected physical result (Figure 8B), and lets users select their nail curvature to compensate in our optimization algorithm for different incident angles of the light, i.e. a slanted nail will be illuminated by the projector for longer (Figure 8C). Finally, the user aligns the textures onto their fingernails (Figure 8D) using the camera feed from our integrated webcam (Logitech C920) using drag gestures to relocate each texture patch. By clicking on 'Start', the system starts the saturation step with UV light and the desaturation step with the RGB projection.

[6]DFRobot Raspberry Pi LCD 7-inch Touchscreen https://dk.rs-online.com/web/p/raspberry-pi-skaerme/2473220
[7]Raspberry Pi Camera Module 2 https://www.raspberrypi.com/products/camera-module-v2/
[8]Everix 535nm Bandpass Filter https://www.edmundoptics.com/p/everix-ultra-thin-od-2-bandpass-filter-535nm-125mm-dia/48719/

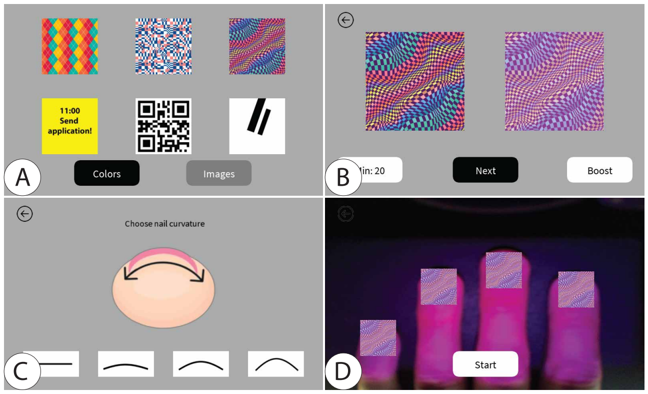

Figure 8: Four pages from the user interface. Users can: (A) choose their nail design, (B) simulated the reprogrammed nail, (C) select the user's nail curvature, and (D) align the images on each nail using a pan gesture.

3 APPLICATION EXAMPLES

Reprogrammable nails as an on-body interface enables a wide range of novel applications. In this section, we outline four application examples to demonstrate our system's capabilities.

3.1 On-body reprogrammable QR codes

Photochromic nail polish can serve as on-body reprogrammable information markers, offering a unique way to include digital information on your body (Figure 9). We integrated QR codes, a versatile way of giving easy access to all sorts of information, e.g. digital business cards.

Figure 9: reprogrammable on-body QR codes

3.2 On-body Calendar

Photochromic nail polish can be used for an on-body calendar, which can be programmed daily or hourly (Figure 10A). Integrating this technology into photochromic nail polish makes it possible to reprogram dates even when they change over the day by syncing them to your online planner.

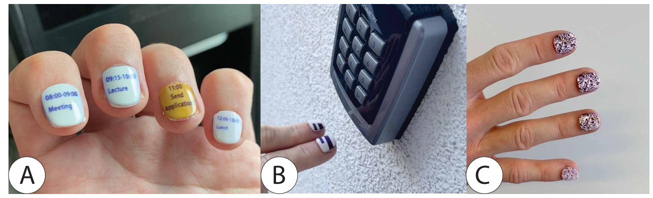

Figure 10: (A) Calendar. (B) Patterns as Access Keys. (C) Fashion Accessory

3.3 On-body Patterns as Access Keys

Using patterns as access keys enable temporary keys that grants access to buildings or rooms, see figure 10B. Instead of QR codes, an authentication process involving two fingers adds complexity and makes replication difficult. Moreover, one can control the desaturation duration within an interval, while leaving no digital traces behind. This method provides convenience, eliminating the need to carry or remember physical keys, as access credentials are always ready at hand.

3.4 Fashion Accessory

While using ChromaNails as a fashion accessory does not present an on-body interface, the technology enables creating a wide range of multi-colored high-resolution textures, see figure 10C. Thus, it is evident that using this technology for fashionable purposes aligns with the traditional function of nail polish. However, ChromaNails presents nail polish which is easy to reprogram to fit user's desired outfit or to try out new designs.

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