Embedding Digital Capabilities in Physical Objects

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Turing's Venner
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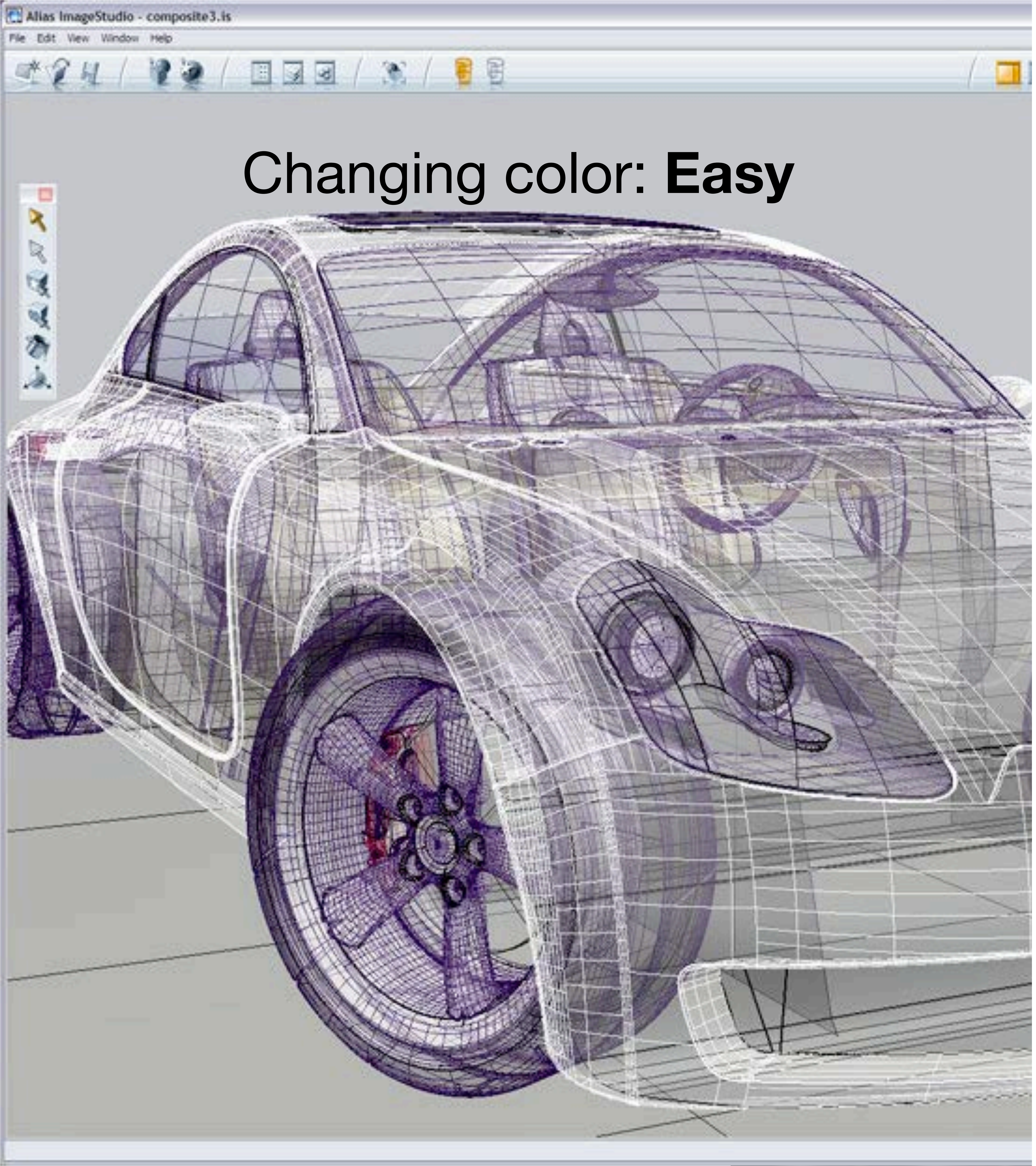
Computing enables opportunities
that are difficult to achieve in the physical world



Changing color: **Easy**

Changing color: **Hard**

How can we embed computing seamlessly into **everyday objects**?

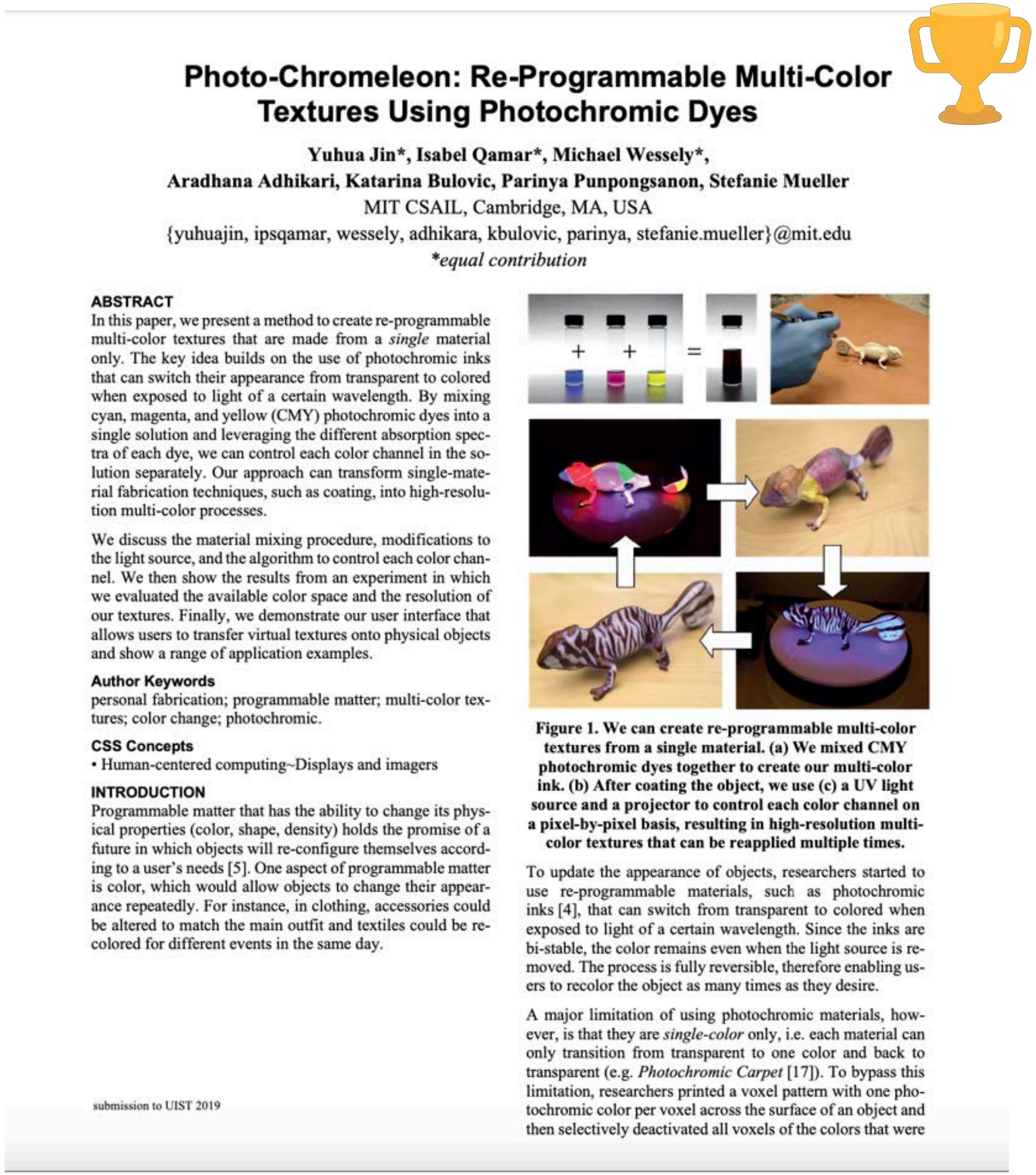


Photo-Chromeleon: Re-Programmable Multi-Color Textures Using Photochromic Dyes

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ABSTRACT

In this paper, we present a method to create re-programmable multi-color textures that are made from a *single* material only. The key idea builds on the use of photochromic inks that can switch their appearance from transparent to colored when exposed to light of a certain wavelength. By mixing cyan, magenta, and yellow (CMY) photochromic dyes into a single solution and leveraging the different absorption spectra of each dye, we can control each color channel in the solution separately. Our approach can transform single-material fabrication techniques, such as coating, into high-resolution multi-color processes.

We discuss the material mixing procedure, modifications to the light source, and the algorithm to control each color channel. We then show the results from an experiment in which we evaluated the available color space and the resolution of our textures. Finally, we demonstrate our user interface that allows users to transfer virtual textures onto physical objects and show a range of application examples.

Author Keywords

personal fabrication; programmable matter; multi-color textures; color change; photochromic.

CSS Concepts

- Human-centered computing~Displays and imagers

INTRODUCTION

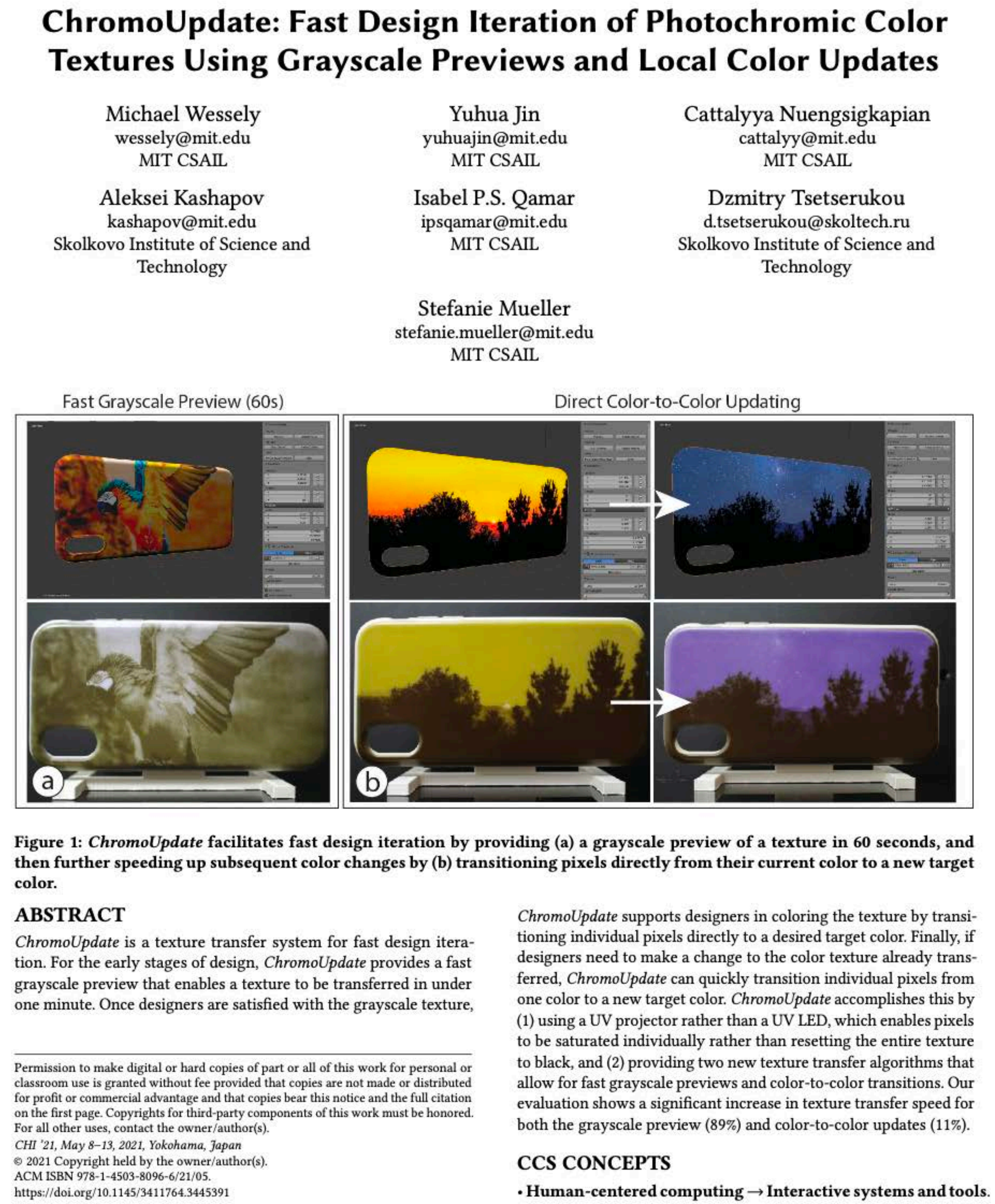
Programmable matter that has the ability to change its physical properties (color, shape, density) holds the promise of a future in which objects will re-configure themselves according to a user's needs [5]. One aspect of programmable matter is color, which would allow objects to change their appearance repeatedly. For instance, in clothing, accessories could be altered to match the main outfit and textiles could be recolored for different events in the same day.

Figure 1. We can create re-programmable multi-color textures from a single material. (a) We mixed CMY photochromic dyes together to create our multi-color ink. (b) After coating the object, we use (c) a UV light source and a projector to control each color channel on a pixel-by-pixel basis, resulting in high-resolution multi-color textures that can be reapplied multiple times.

To update the appearance of objects, researchers started to use re-programmable materials, such as photochromic inks [4], that can switch from transparent to colored when exposed to light of a certain wavelength. Since the inks are bi-stable, the color remains even when the light source is removed. The process is fully reversible, therefore enabling users to recolor the object as many times as they desire.

A major limitation of using photochromic materials, however, is that they are *single-color* only, i.e. each material can only transition from transparent to one color and back to transparent (e.g. *Photochromic Carpet* [17]). To bypass this limitation, researchers printed a voxel pattern with one photochromic color per voxel across the surface of an object and then selectively deactivated all voxels of the colors that were

submission to UIST 2019



ChromoUpdate: Fast Design Iteration of Photochromic Color Textures Using Grayscale Previews and Local Color Updates

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Figure 1: *ChromoUpdate* facilitates fast design iteration by providing (a) a grayscale preview of a texture in 60 seconds, and then further speeding up subsequent color changes by (b) transitioning pixels directly from their current color to a new target color.

ABSTRACT

ChromoUpdate is a texture transfer system for fast design iteration. For the early stages of design, *ChromoUpdate* provides a fast grayscale preview that enables a texture to be transferred in under one minute. Once designers are satisfied with the grayscale texture, *ChromoUpdate* supports designers in coloring the texture by transitioning individual pixels directly to a desired target color. Finally, if designers need to make a change to the color texture already transferred, *ChromoUpdate* can quickly transition individual pixels from one color to a new target color. *ChromoUpdate* accomplishes this by (1) using a UV projector rather than a UV LED, which enables pixels to be saturated individually rather than resetting the entire texture to black, and (2) providing two new texture transfer algorithms that allow for fast grayscale previews and color-to-color transitions. Our evaluation shows a significant increase in texture transfer speed for both the grayscale preview (89%) and color-to-color updates (11%).

CCS CONCEPTS

- **Human-centered computing → Interactive systems and tools.**

CHI '21, May 8–13, 2021, Yokohama, Japan

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https://doi.org/10.1145/3411764.3445391


airbrush
photochromic coating

one side: 30 min
four sides: 120 min

the same phone case in all three images

Texture Transfer Speed: 20-40min

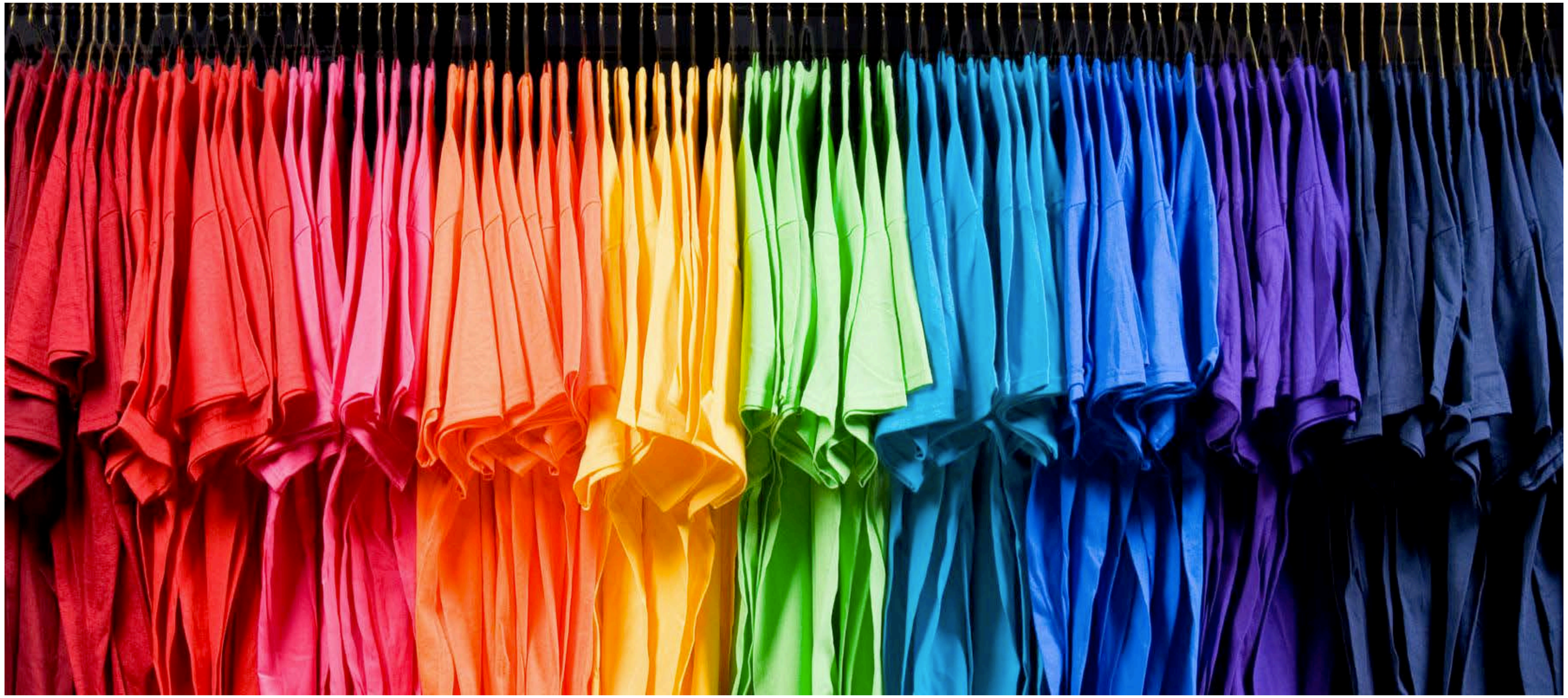
the same shoe in both images

Texture Transfer Speed: 45min

the same car in both images

Texture Transfer Speed: 20-30min

Reprogrammable Fibre



Chromanails: Reprogramming Fingernails

Photochromic
Nailpolish

Reprogrammer

Reprogrmmable
Fingernail Texture


ATCHIT LAB
Firebase
ChromoNails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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)**.

KEYWORDS

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

ACM Reference Format:
Magnus Frisk, Mads Kristian Steen Vejrup, Frederik Kjær Sørensen, and Michael Wessely. 2023. ChromaNails: Re-Programmable Multi-Colored High-Resolution On-Body Interfaces using Photochromic Nail Polish. In *The 36th Annual ACM Symposium on User Interface Software and Technology (UIST '23 Adjunct), October 29–November 01, 2023, San Francisco, CA, USA.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3586182.3615824

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

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*equal contribution

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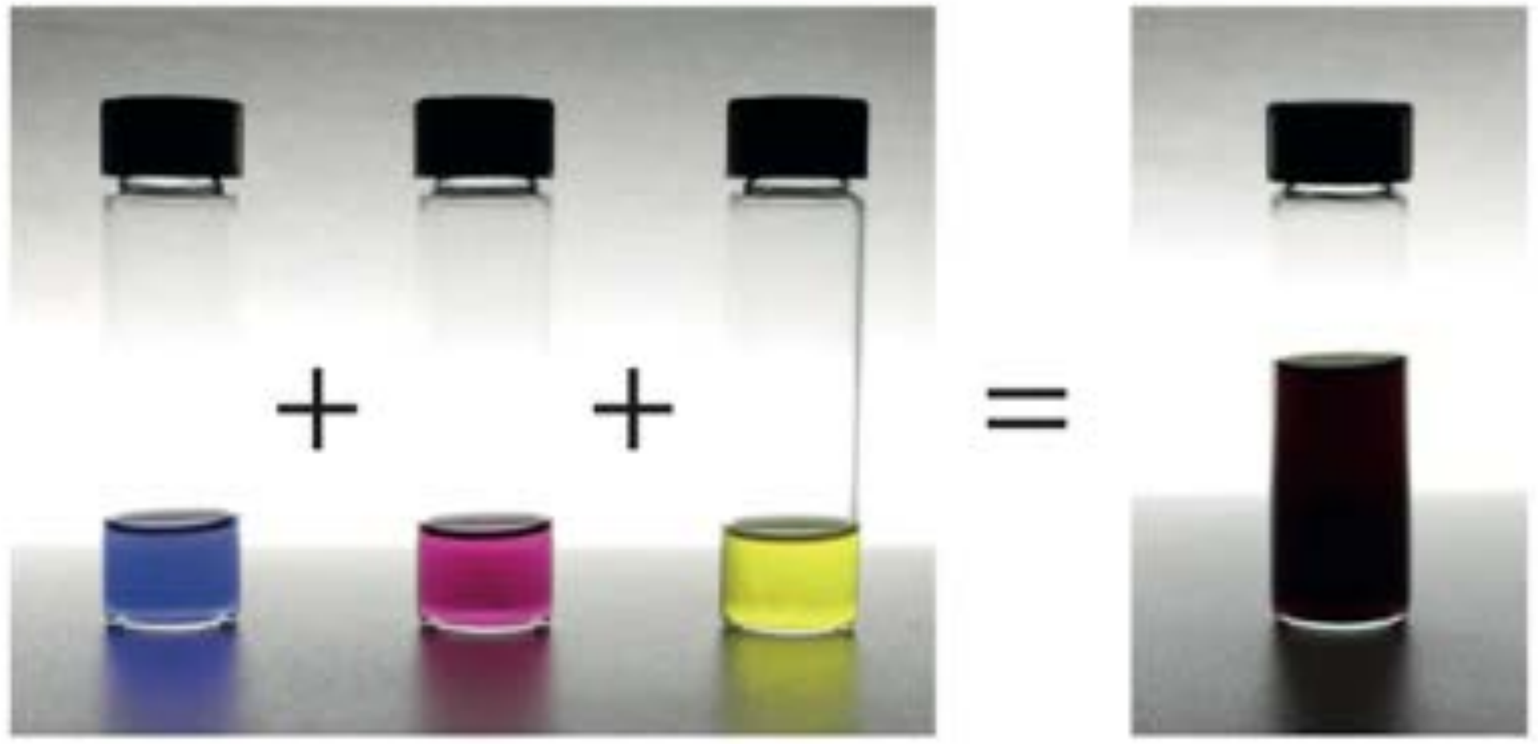
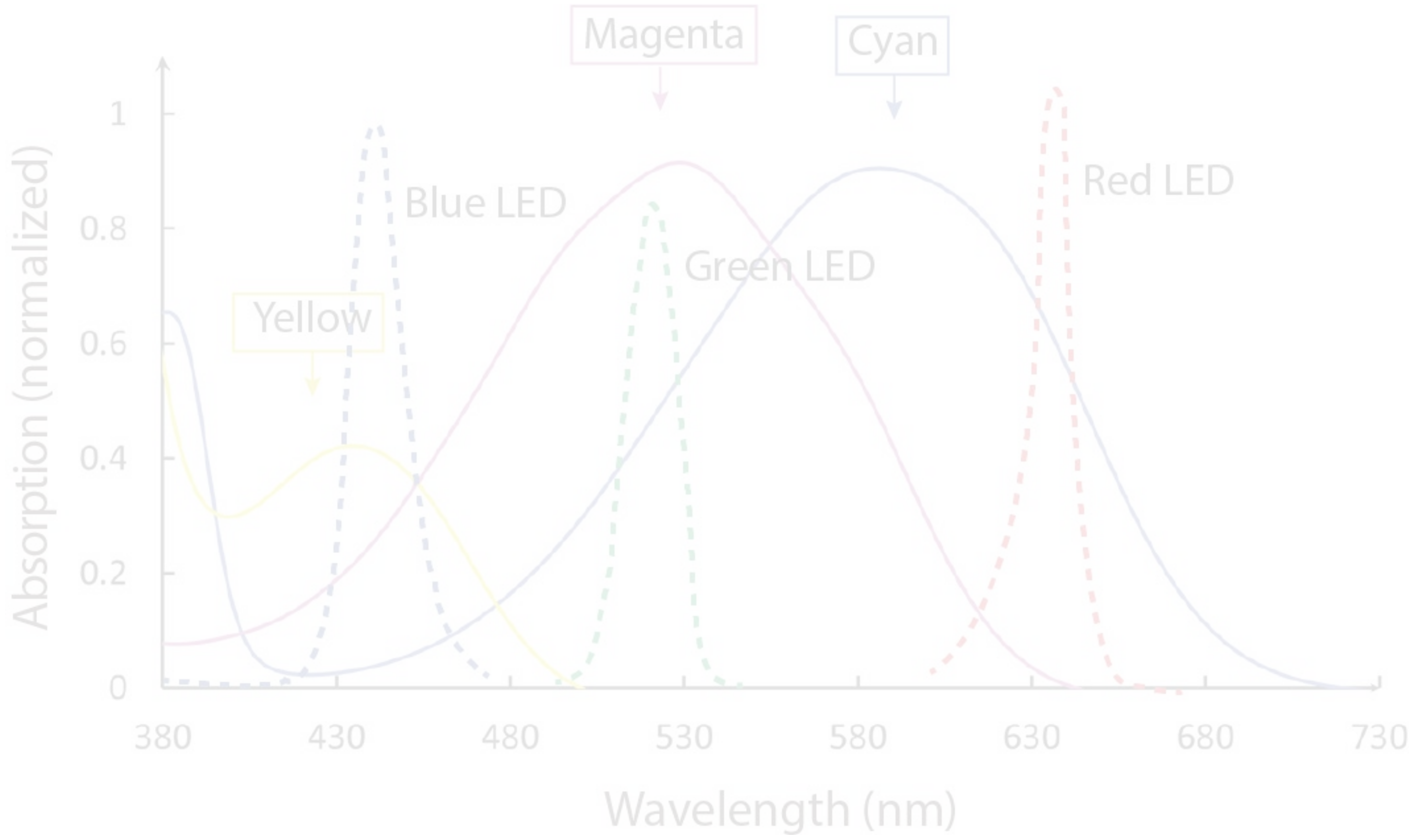
https://doi.org/10.1145/3586182.3615824

Key Contributions

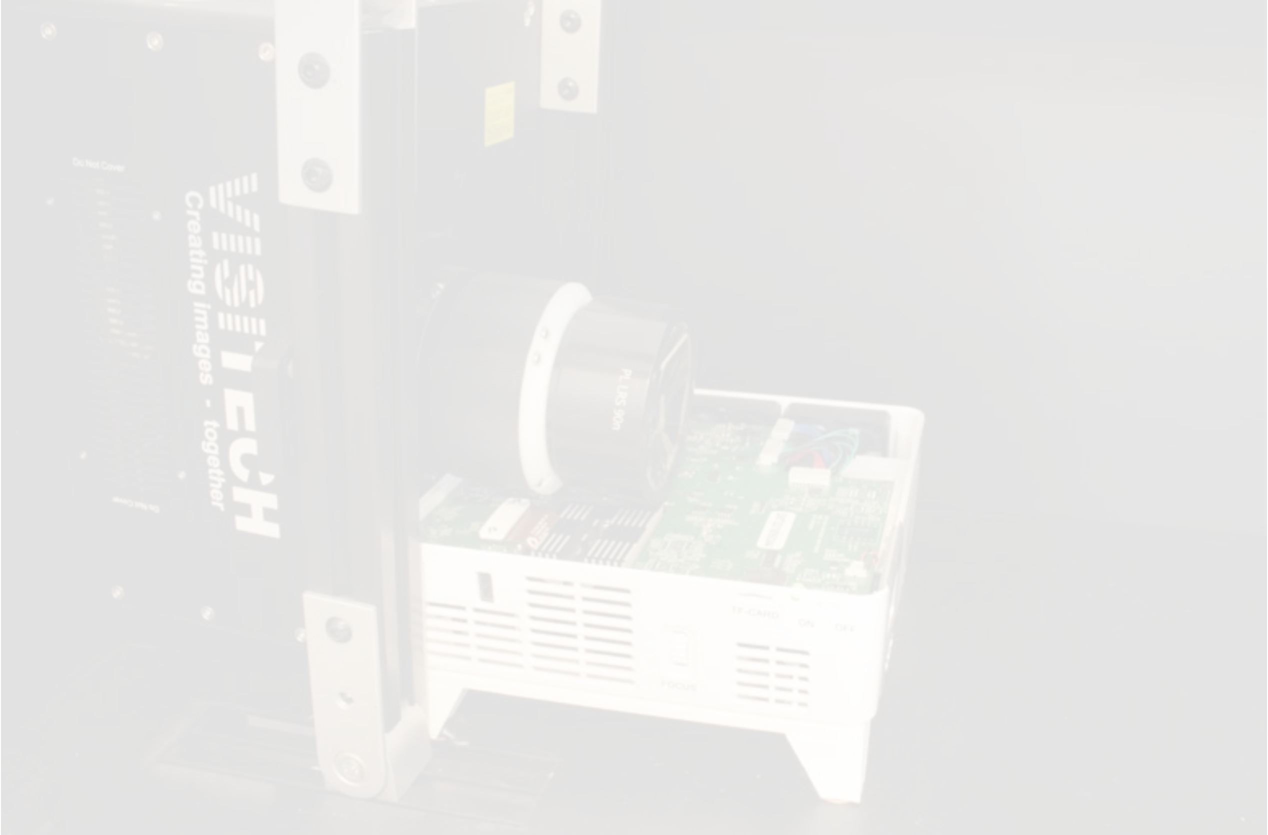


Reprogrammable Multicolor Ink
Using photochromic dyes

$$\min_{t} F(t) = (C(t) - B)^2$$



Computational model
Controlling individual saturation levels

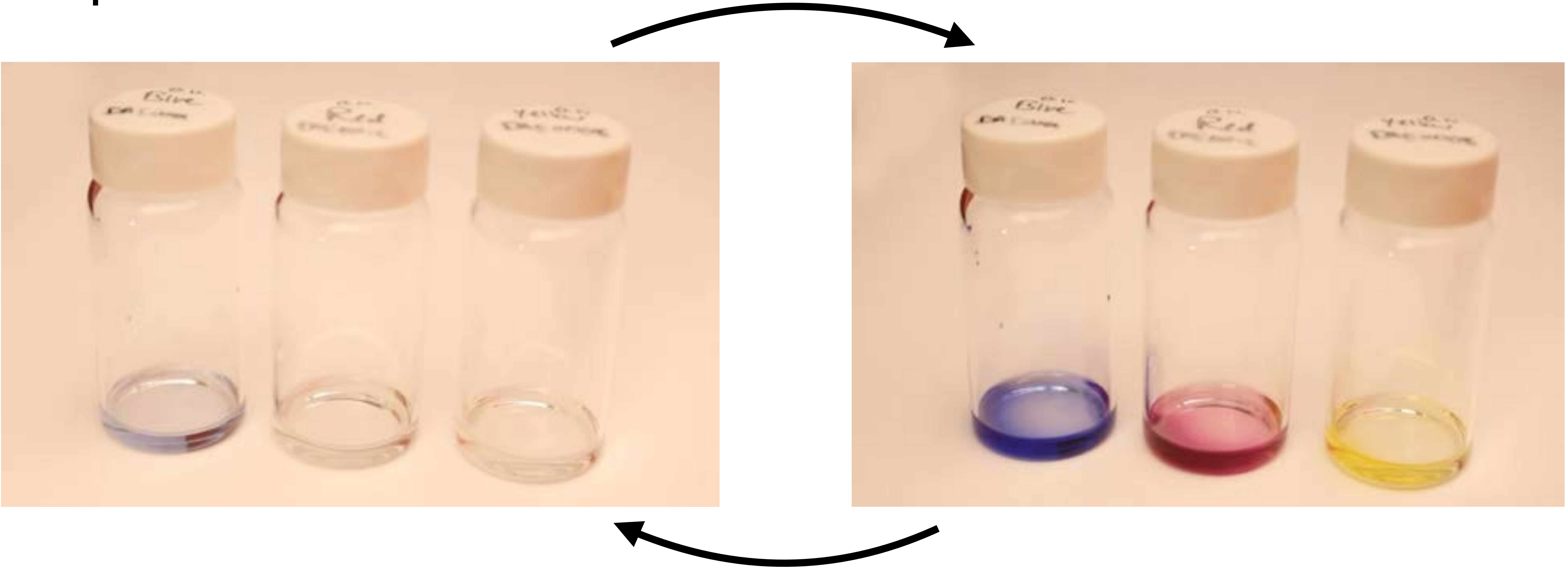


Coating & Hardware System
For automatic reprogramming

photochromic dyes

photochromic dyes

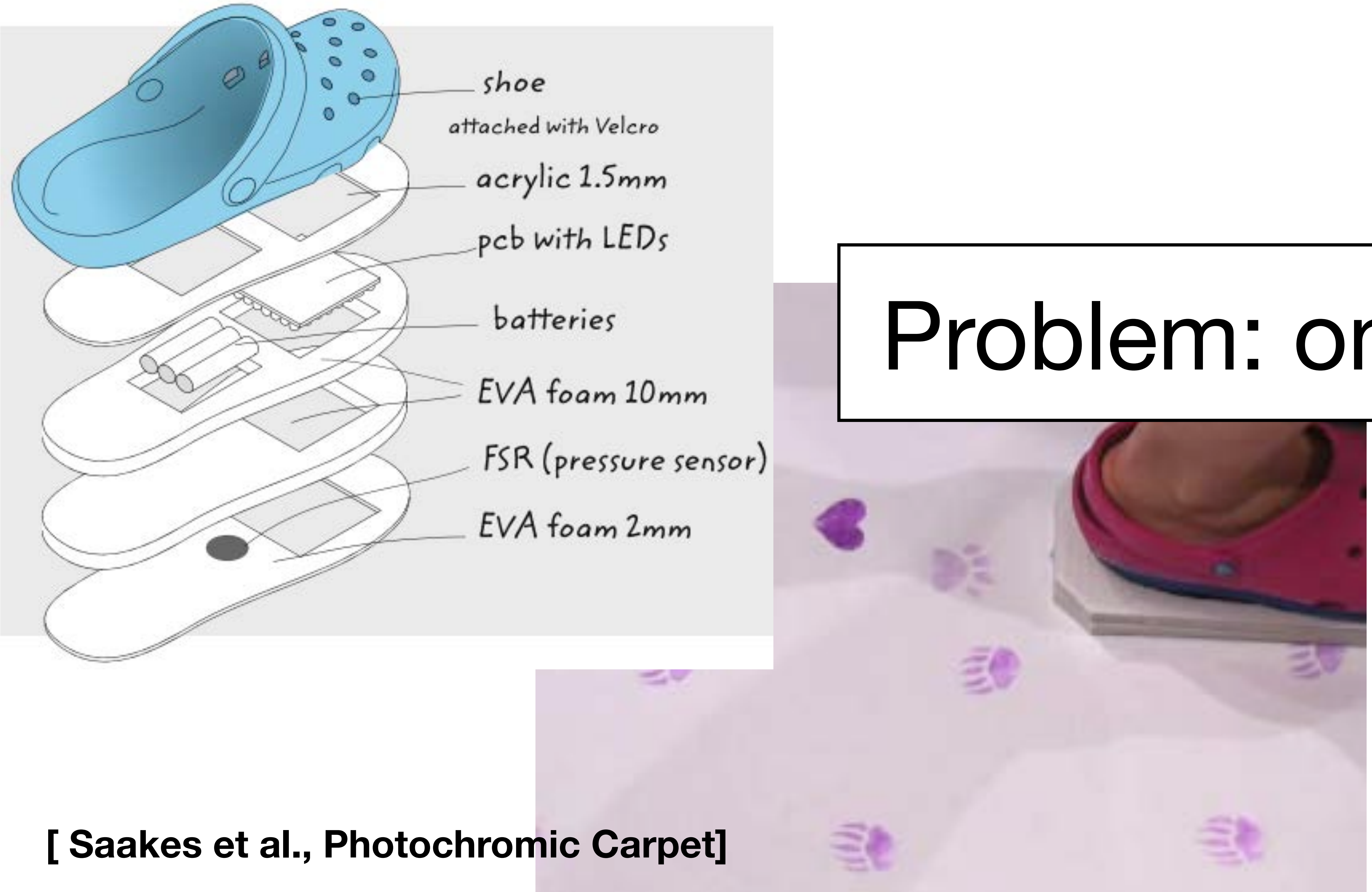
Repeat
Multiple times



20 sec (saturation)
UV light

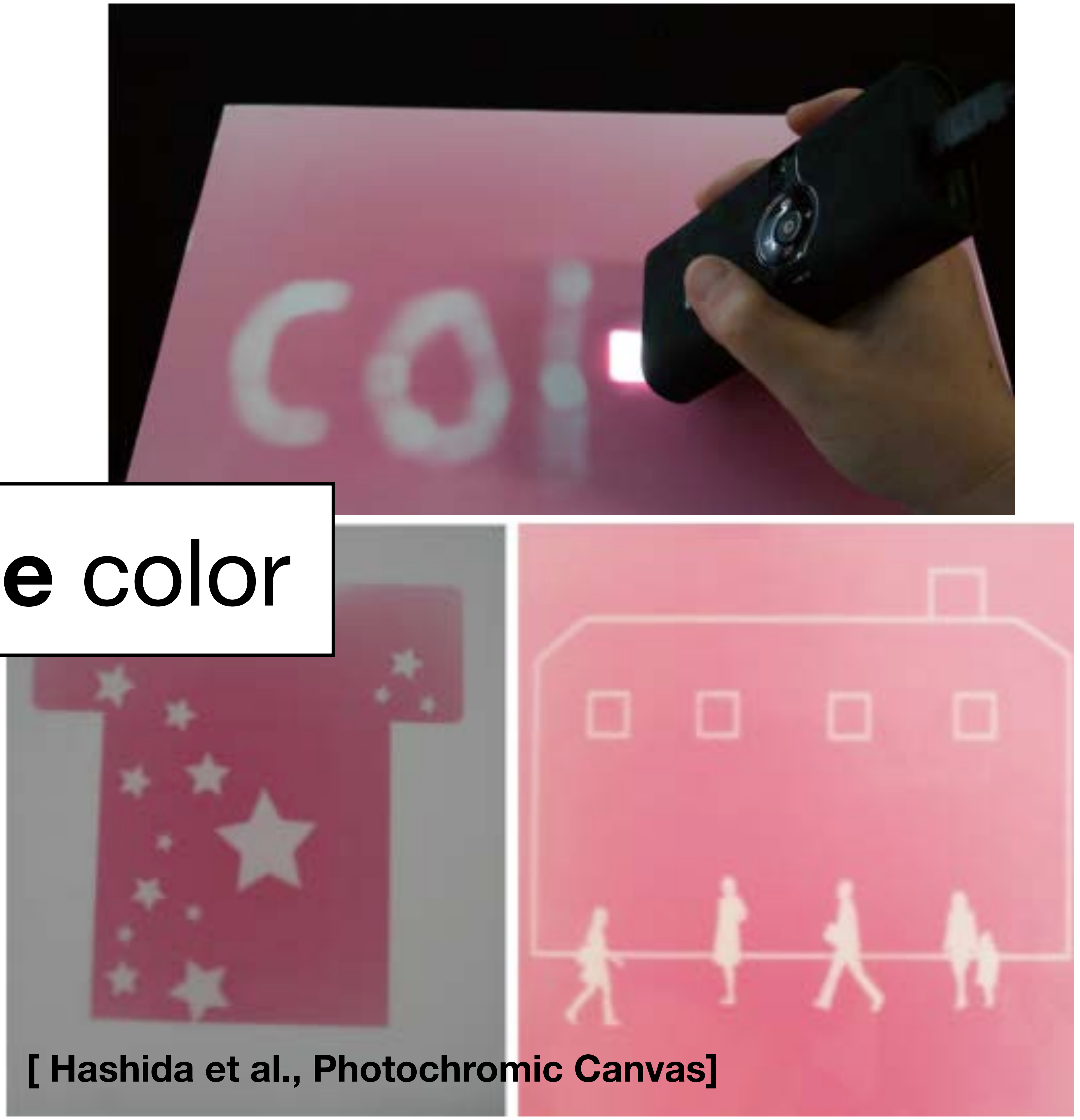
4 min (desaturation)
visible light

Previous Work



[Saakes et al., Photochromic Carpet]

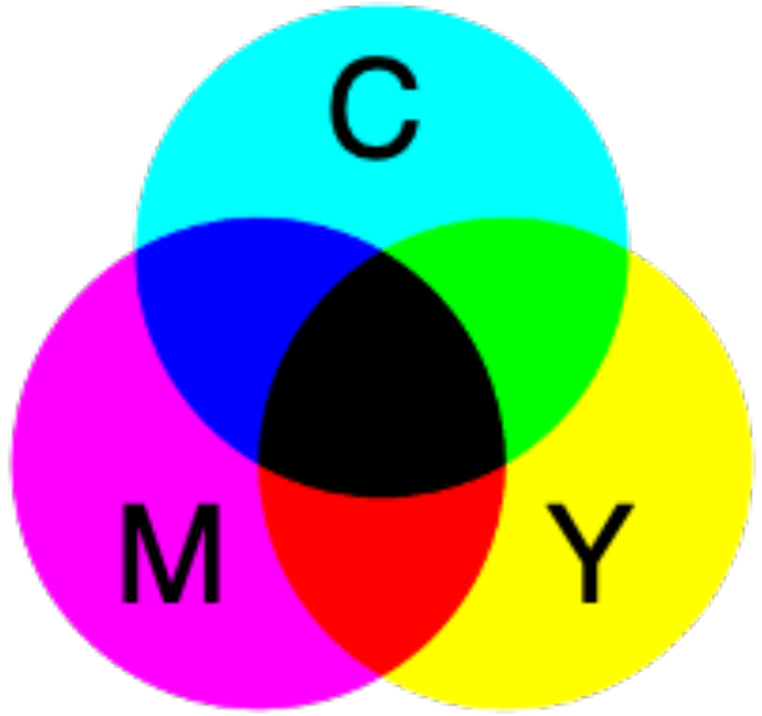
Problem: only **one** color

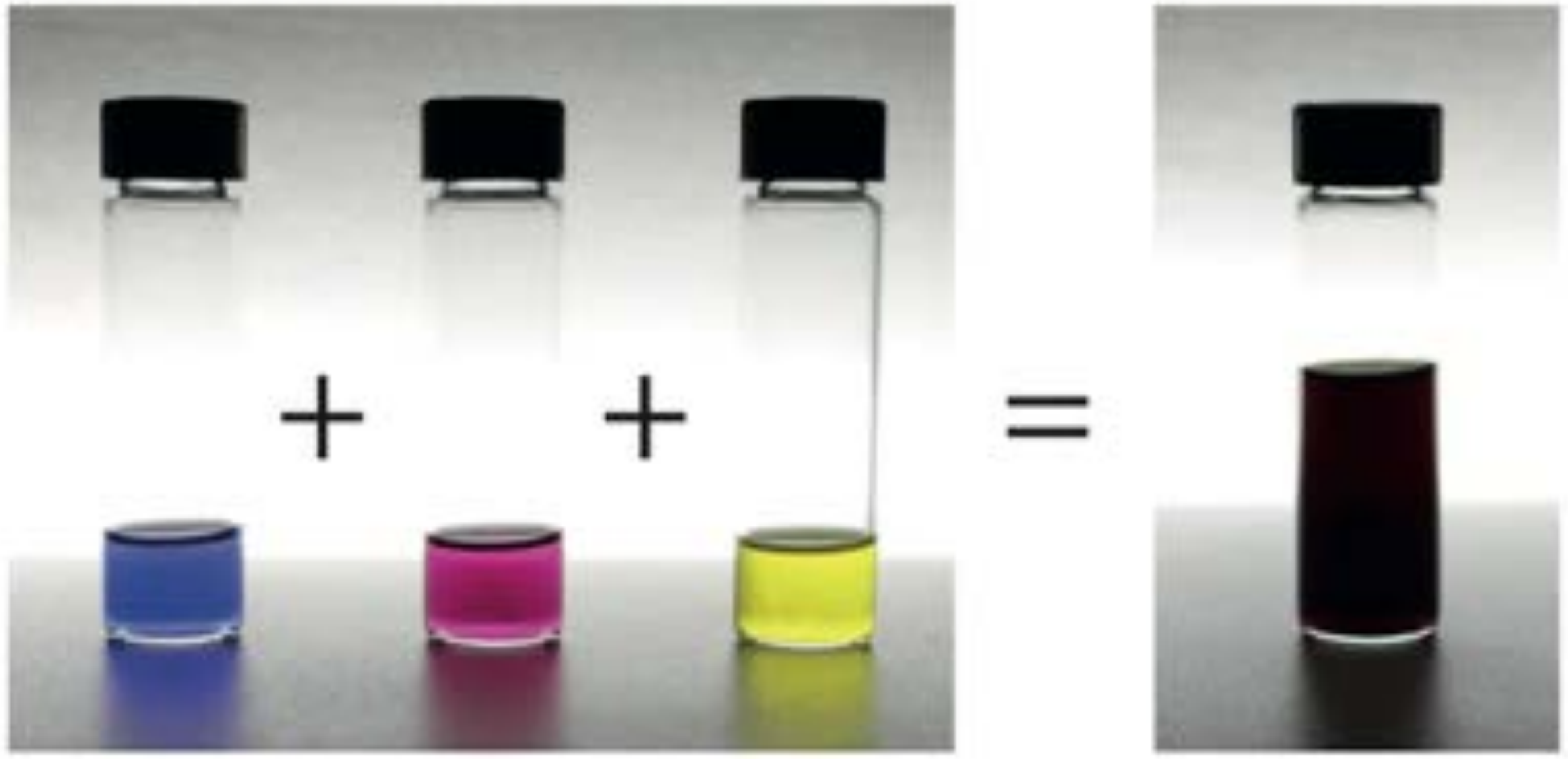


[Hashida et al., Photochromic Canvas]

Our Idea: Mixing cyan, magenta, and yellow dyes

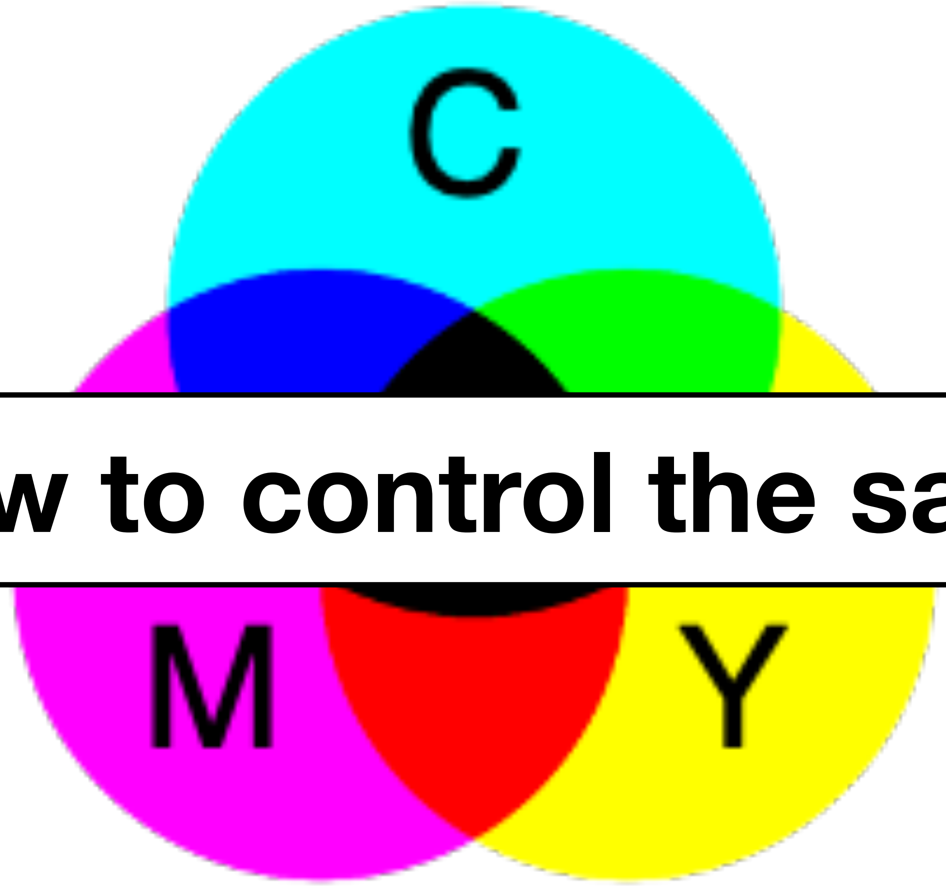
Generating a large color spectrum



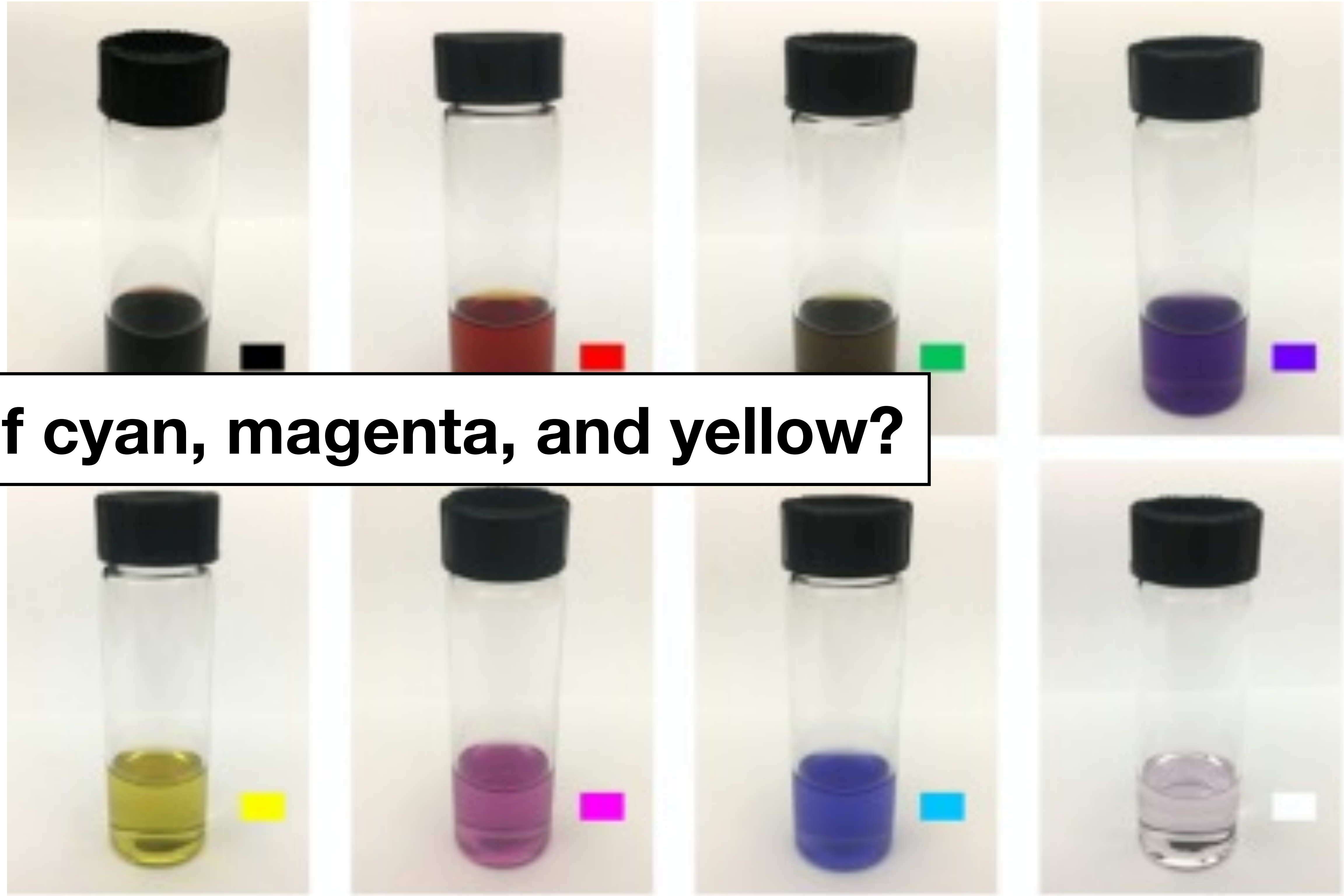


Changing the saturation of each dyes individually produces different colors

CMY mixture

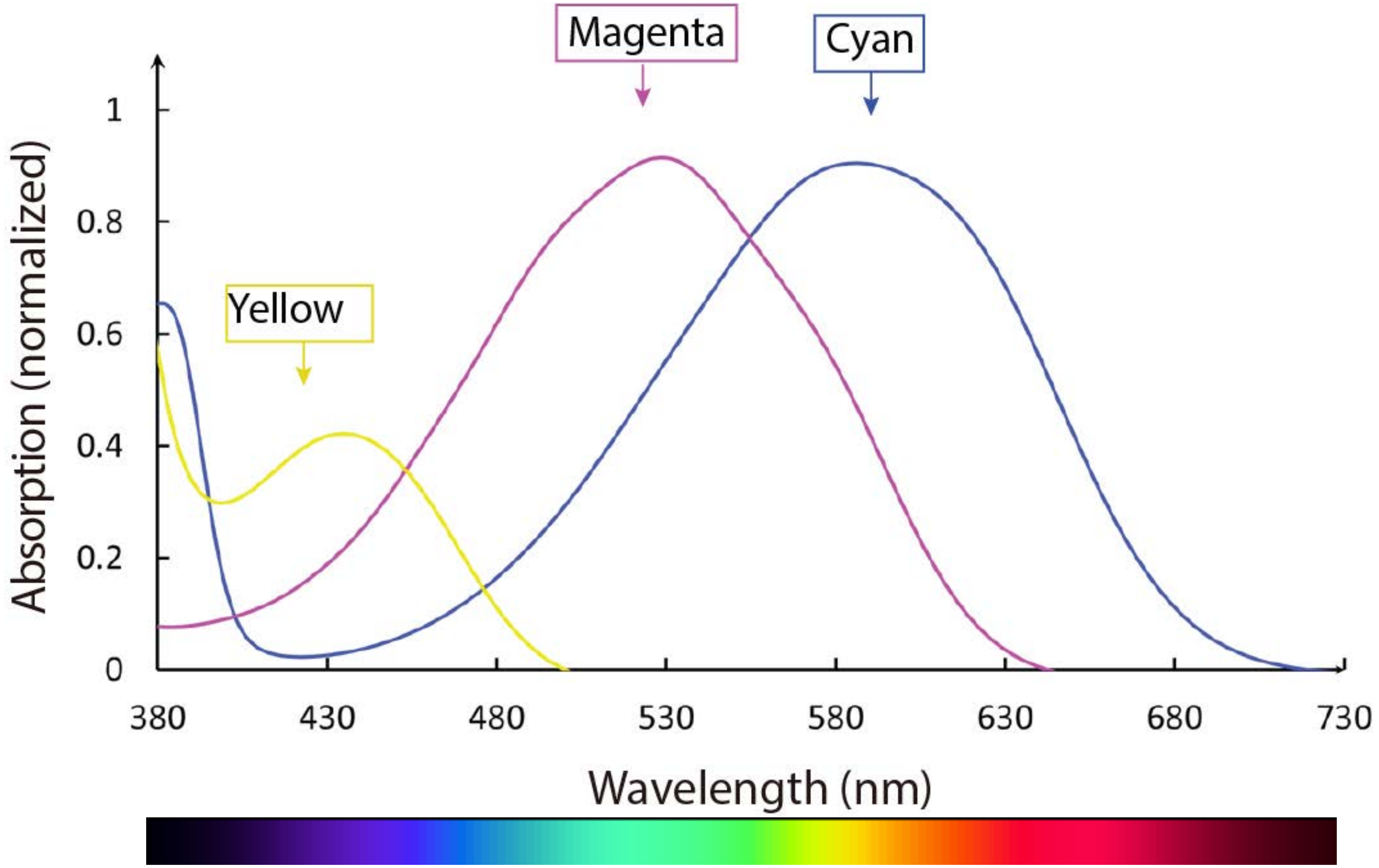


How to control the saturation of cyan, magenta, and yellow?

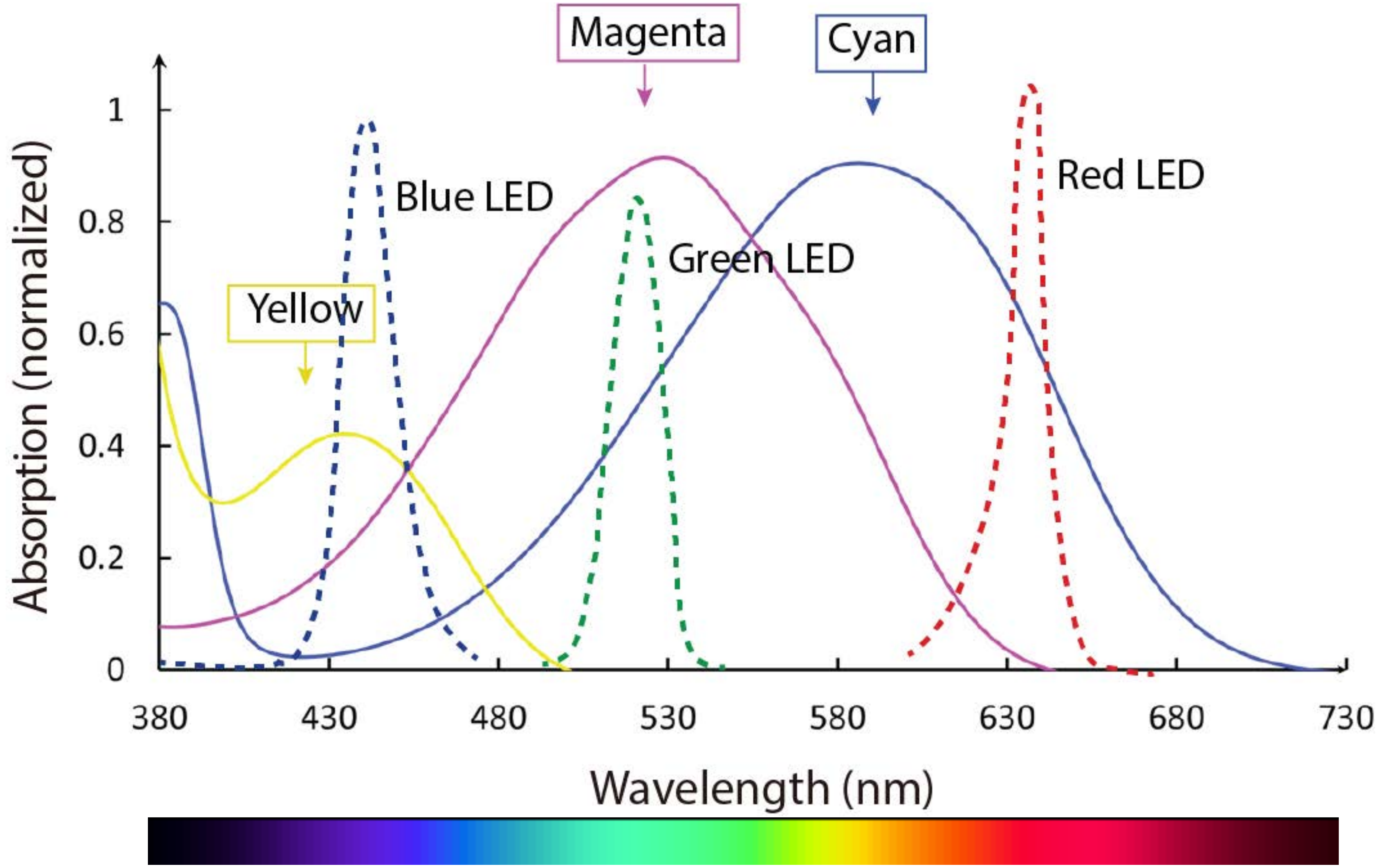


The same liquid in all images

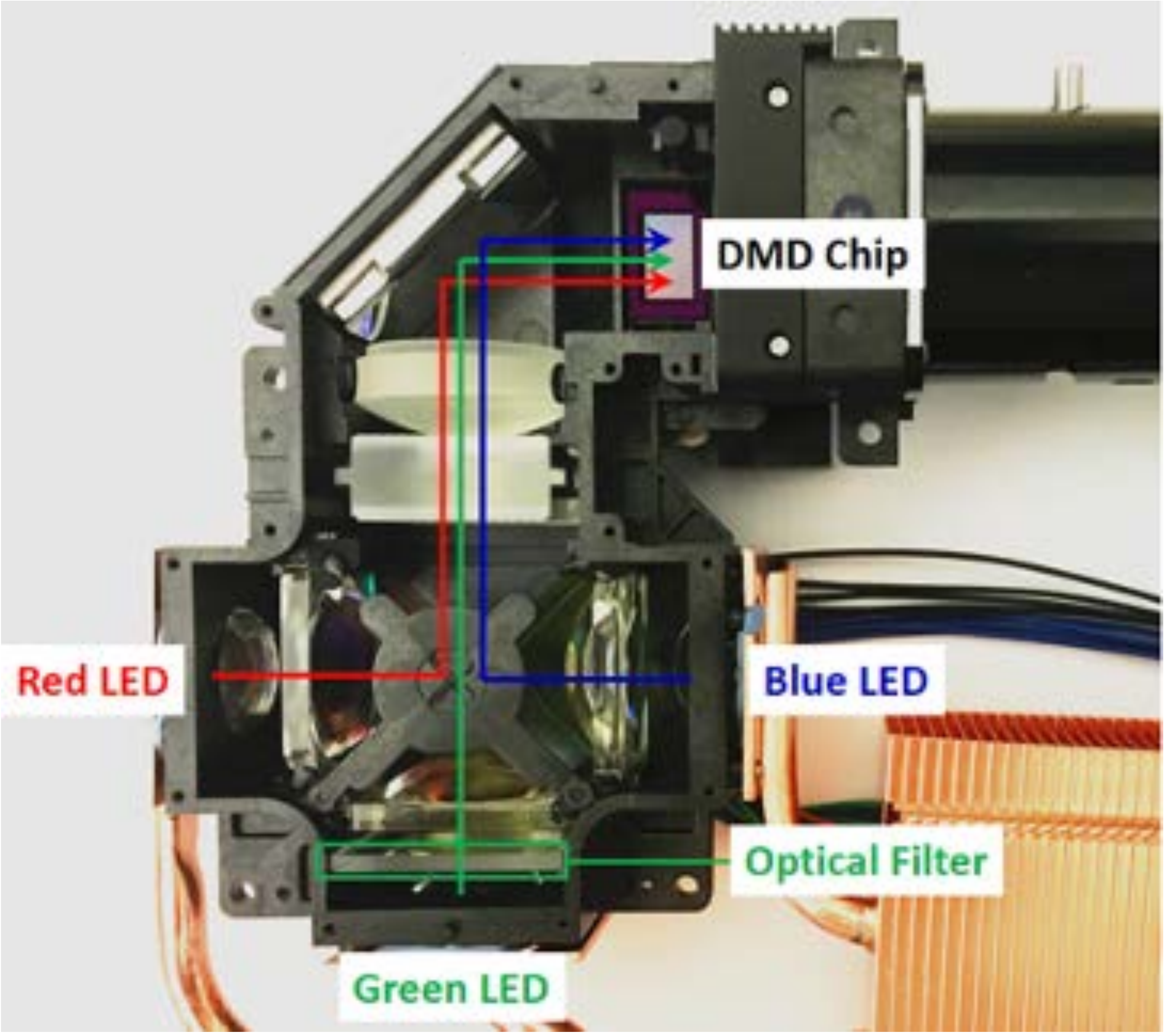
Absorption spectrum of each dye for desaturation:



Shine light of a specific wavelength on the mixture



Regular DLP Projector

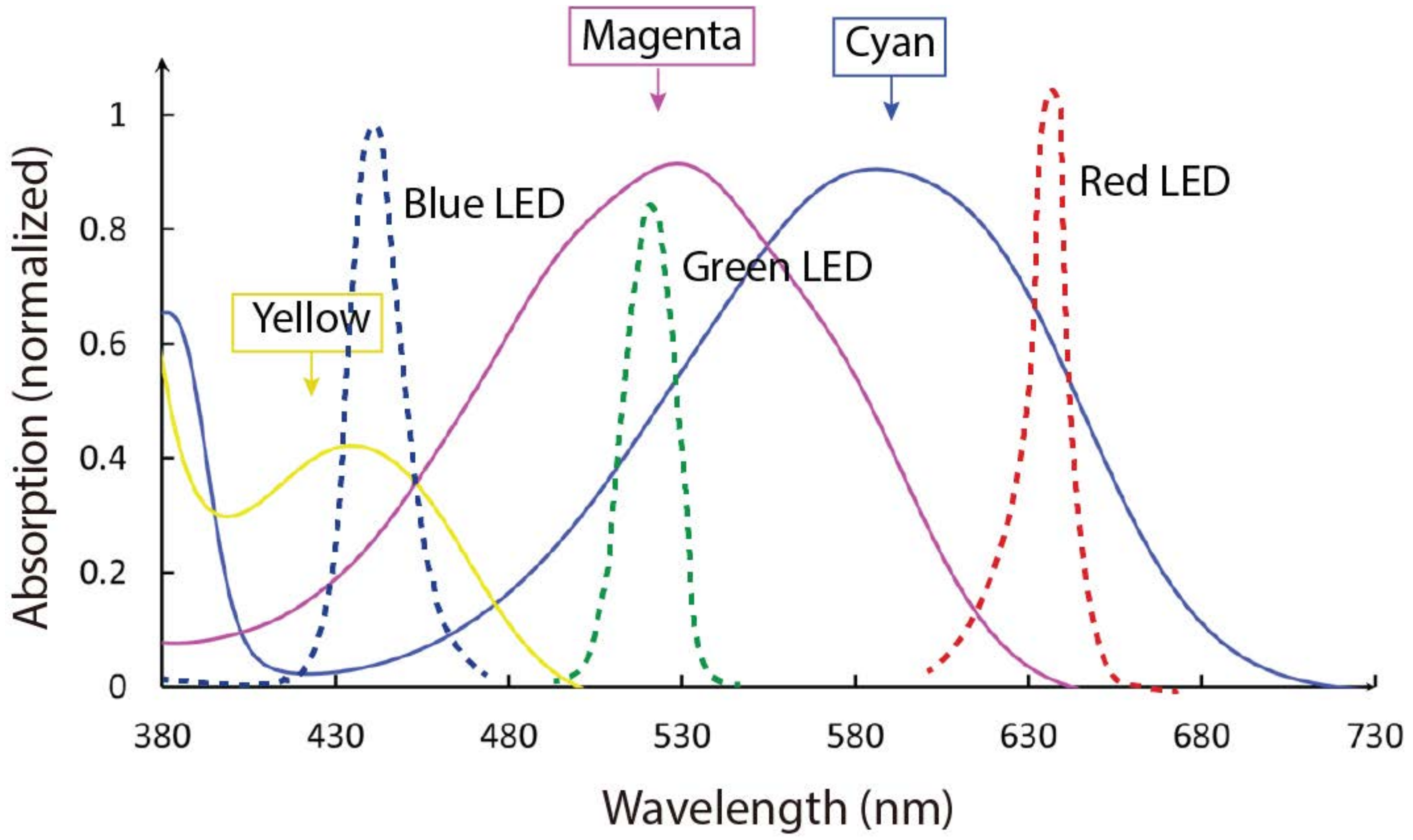


Key Contributions

Reprogrammable Multicolor Ink

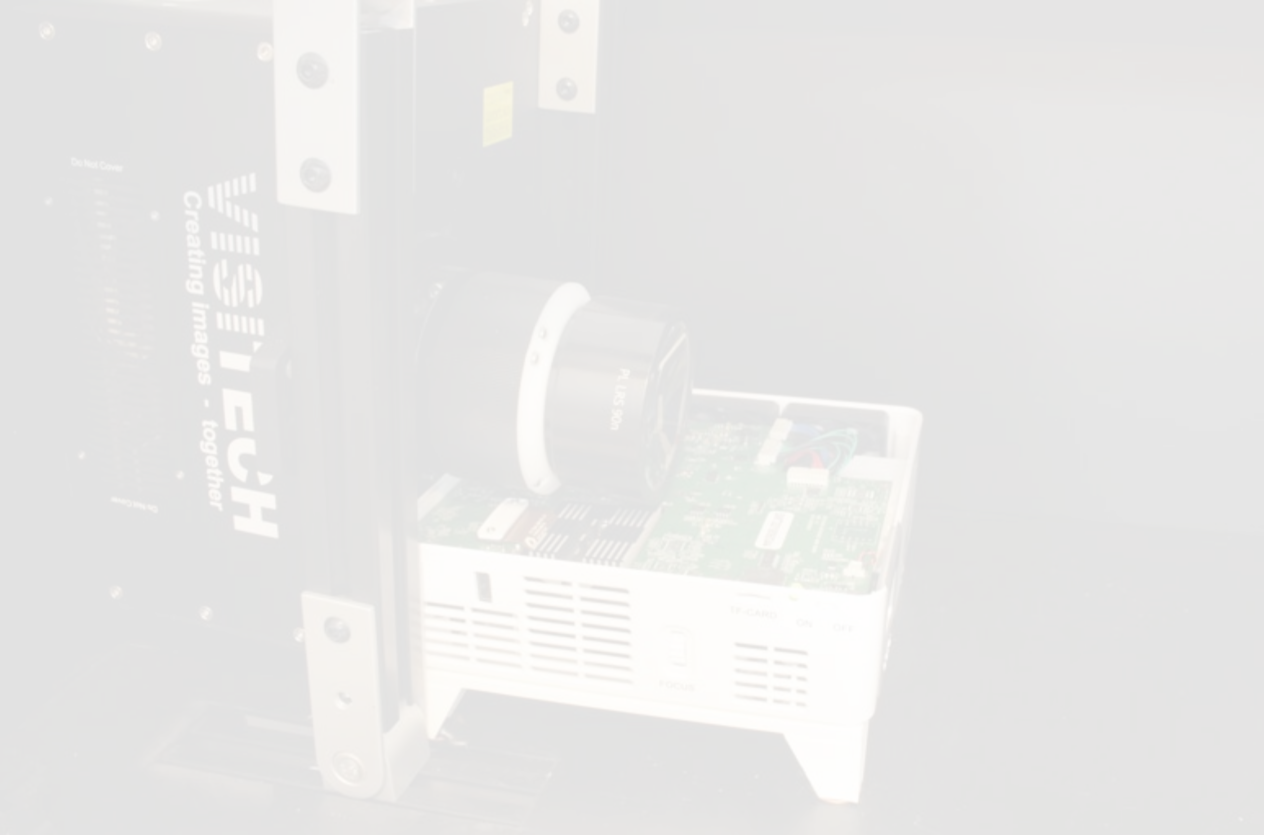
Using photochromic dyes

$$\min_{t} F(t) = (C(t) - B)^2$$



Computational model

Controlling individual saturation levels

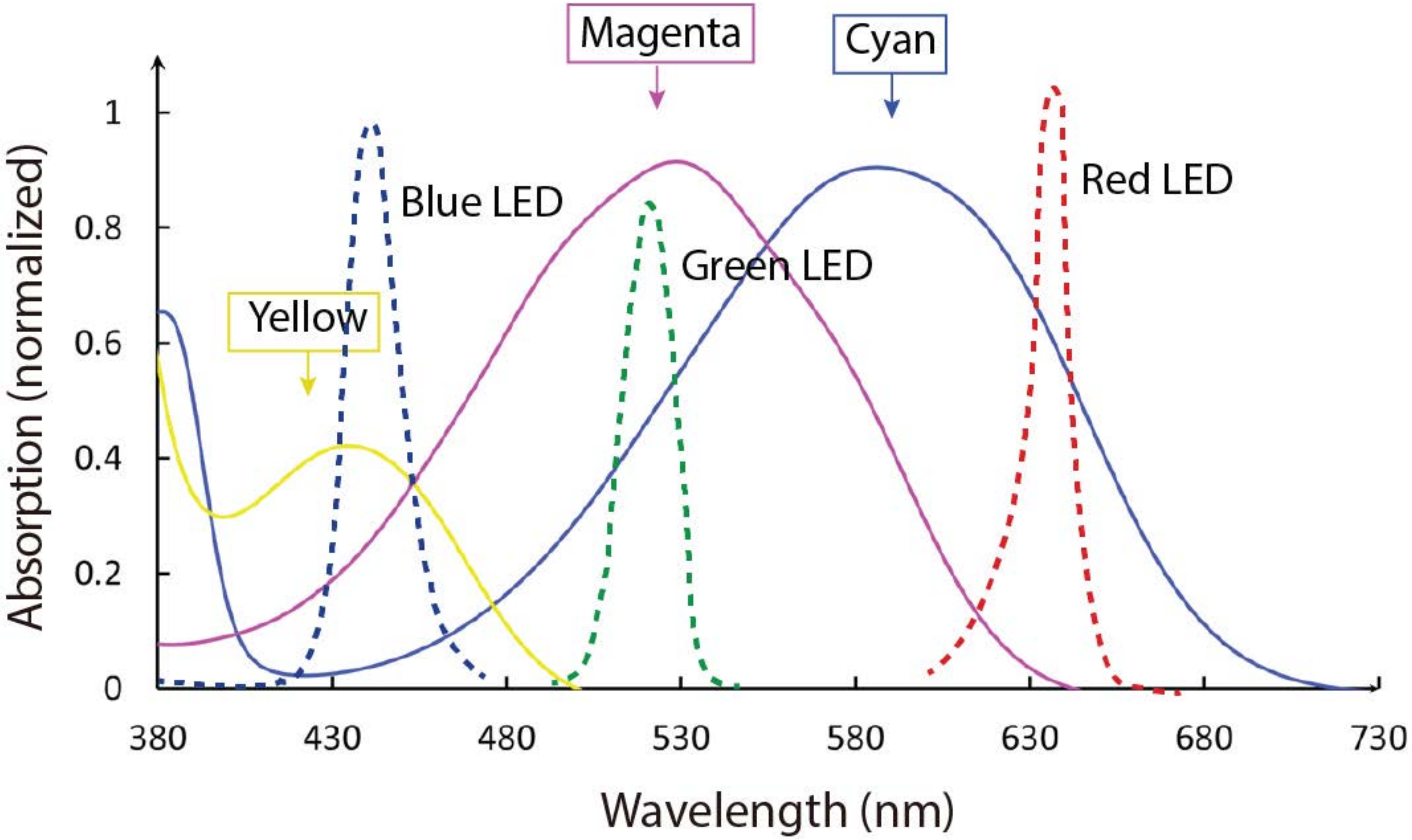


Coating & Hardware System

For automatic reprogramming

RGB light desaturates CMY dyes

But what is the impact of each light source on each dye?



Experiment

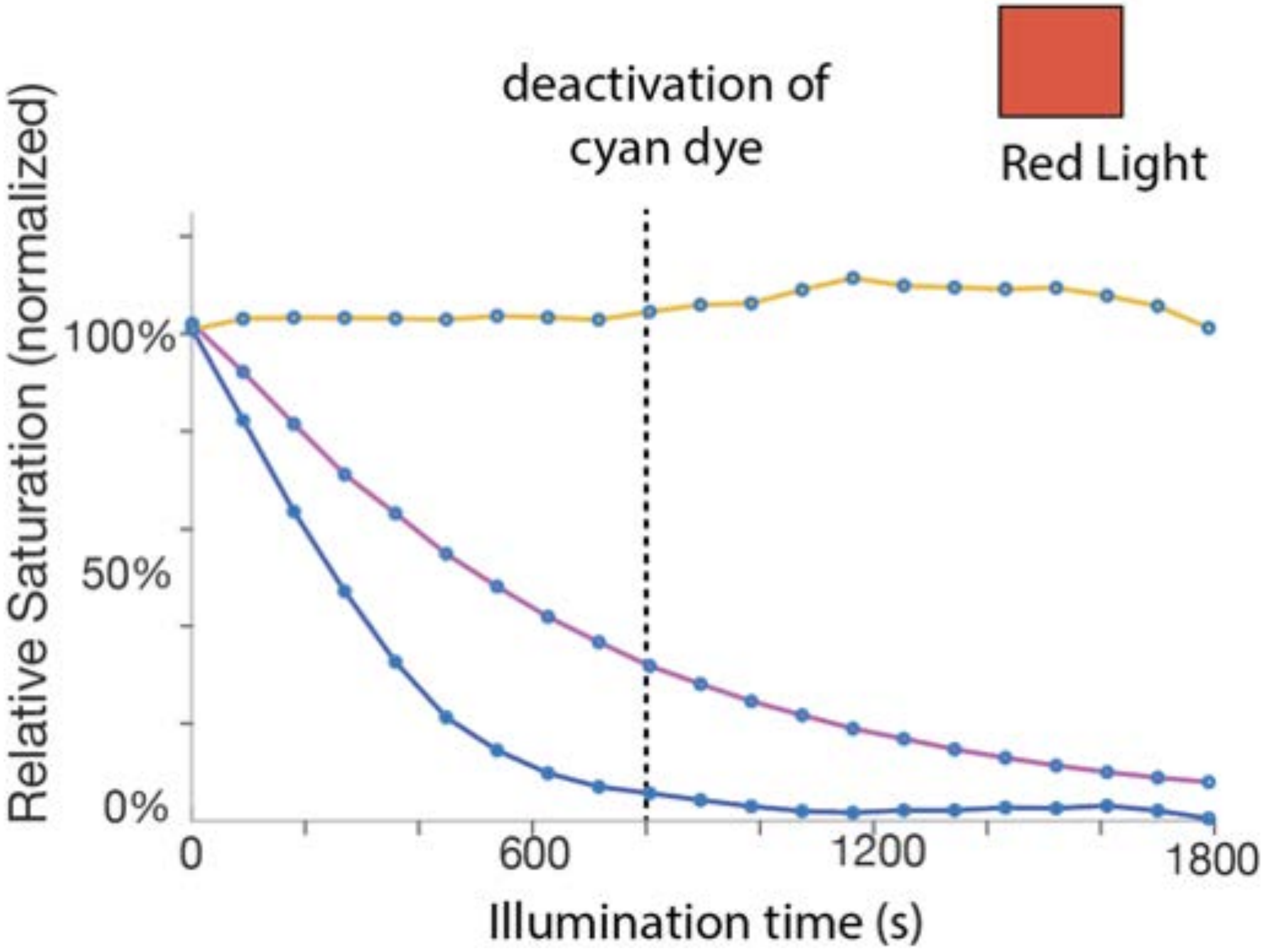
- illuminate each dye with each wavelength
- measure desaturation over time

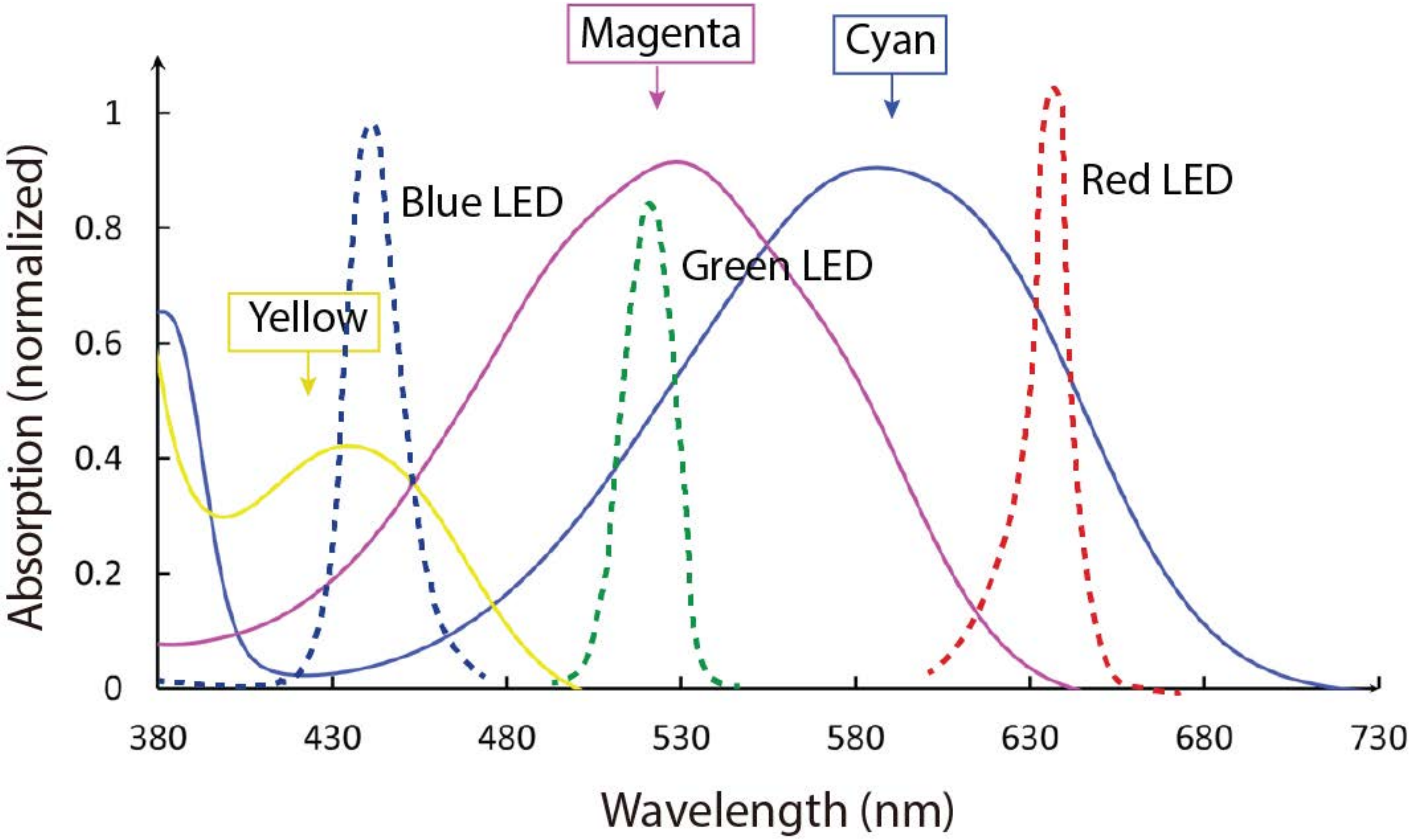
cyan dye

magenta dye

yellow dye

Desaturation times for red light





Goal: Create target color B from Color A

Shine red/green/blue light for a time t = (tr,tg,tb)

Color A

fully saturated CMY (1,1,1)

red light	tr = 200s
green light	tg = 380s
blue light	tb = 20s

→

Color B

Minimize for t

Estimated Color

Target Color

$$\min_{t} F(t) = (C(t) - B)^2$$

Estimate color for given t

$$C_j(t) = X \; - a_j(t_r) - b_j(t_g) - c_j(t_b) \quad j \in c, m, y$$

CMY (1,1,1)

red light for tr seconds

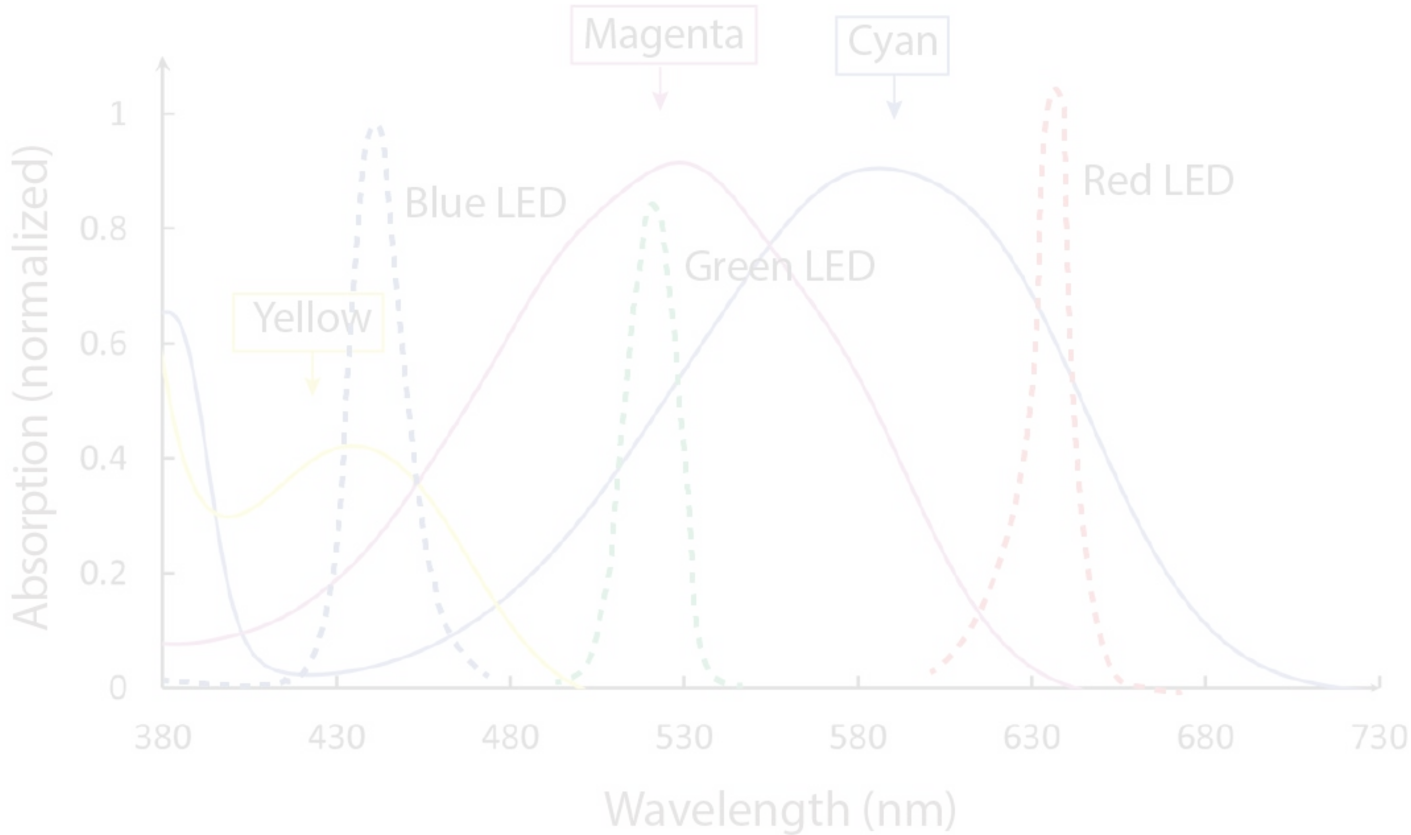
green light for tg seconds

blue light for tb seconds

Key Contributions

Reprogrammable Multicolor Ink
Using photochromic dyes

$$\min_{t} F(t) = (C(t) - B)^2$$



Computational model
Controlling individual saturation levels

Coating & Projector System
For automatic reprogramming


automotive laquer
beaker
vials
mixer
photochromic dyes

mix all three together

airbrush
photochromic coating

User Interface and Projection System


aaxa TECHNOLOGIES
DLP projector (desaturation)
UV light (saturation)
phlatlight

load virtual color texture

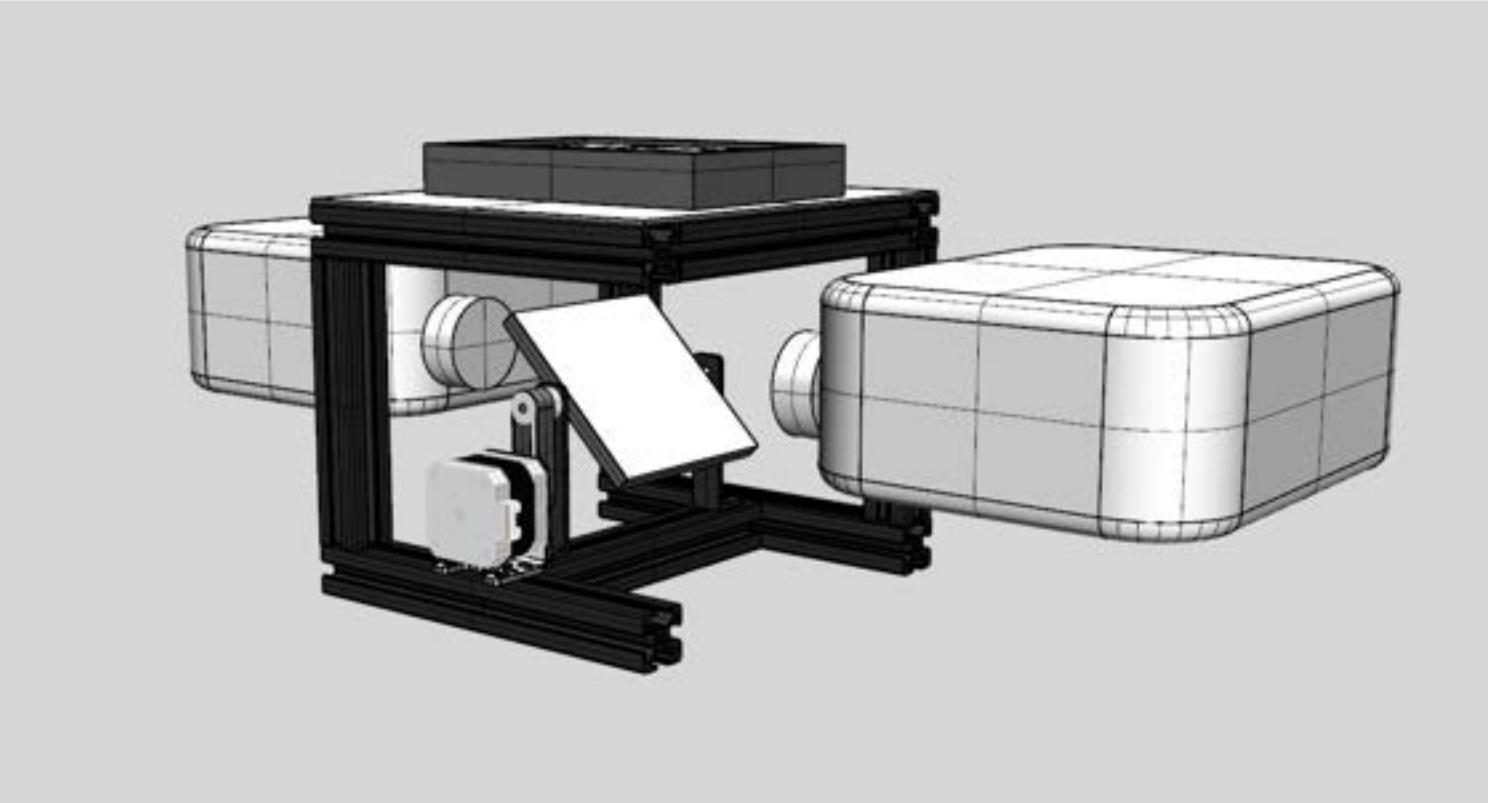
Challenges and Opportunities

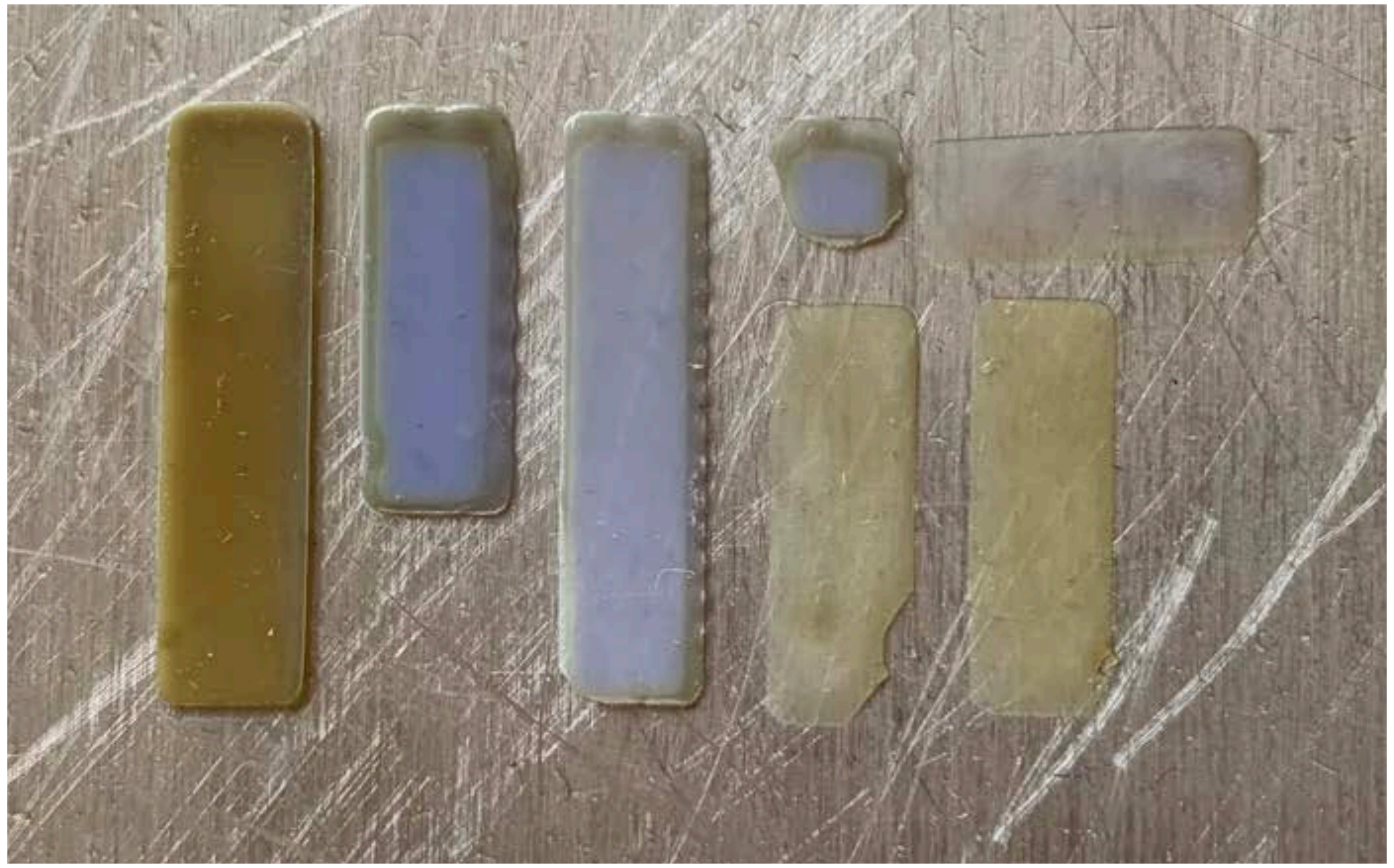
Improving the color gamut

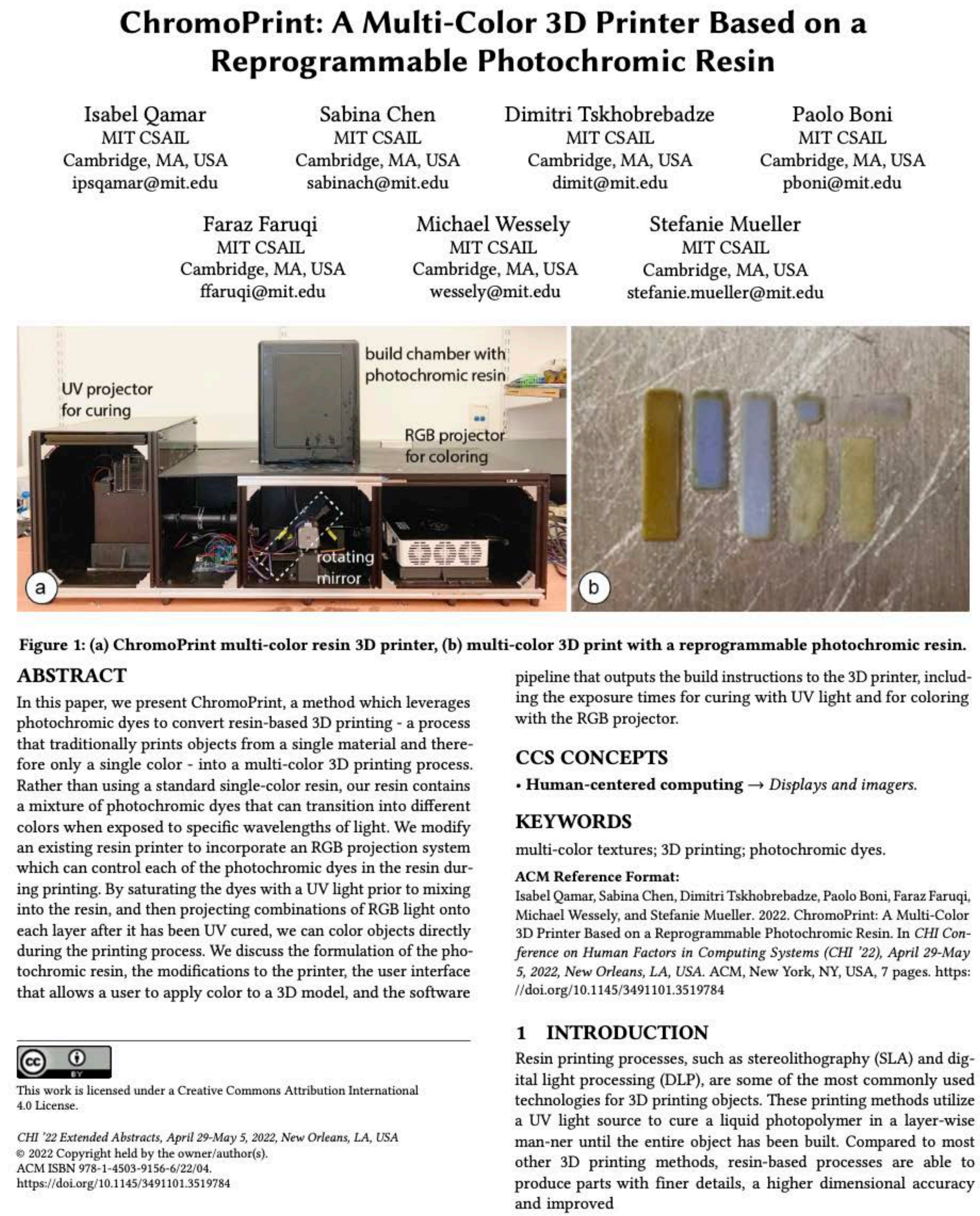
Only a limited amount of colors are commercially available
Limits the overall color gamut

New dyes get developed
Experimental cyan

Multi-Color DLP 3D printer
with photochromic resin







ChromoPrint: A Multi-Color 3D Printer Based on a Reprogrammable Photochromic Resin

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Figure 1: (a) ChromoPrint multi-color resin 3D printer, (b) multi-color 3D print with a reprogrammable photochromic resin.

ABSTRACT

In this paper, we present ChromoPrint, a method which leverages photochromic dyes to convert resin-based 3D printing - a process that traditionally prints objects from a single material and therefore only a single color - into a multi-color 3D printing process. Rather than using a standard single-color resin, our resin contains a mixture of photochromic dyes that can transition into different colors when exposed to specific wavelengths of light. We modify an existing resin printer to incorporate an RGB projection system which can control each of the photochromic dyes in the resin during printing. By saturating the dyes with a UV light prior to mixing into the resin, and then projecting combinations of RGB light onto each layer after it has been UV cured, we can color objects directly during the printing process. We discuss the formulation of the photochromic resin, the modifications to the printer, the user interface that allows a user to apply color to a 3D model, and the software pipeline that outputs the build instructions to the 3D printer, including the exposure times for curing with UV light and for coloring with the RGB projector.

CCS CONCEPTS

• **Human-centered computing** → *Displays and imagers.*

KEYWORDS

multi-color textures; 3D printing; photochromic dyes.

ACM Reference Format:
Isabel Qamar, Sabina Chen, Dimitri Tskhobrebadze, Paolo Boni, Faraz Faruqi, Michael Wessely, and Stefanie Mueller. 2022. ChromoPrint: A Multi-Color 3D Printer Based on a Reprogrammable Photochromic Resin. In *CHI Conference on Human Factors in Computing Systems (CHI '22), April 29-May 5, 2022, New Orleans, LA, USA.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3491101.3519784

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https://doi.org/10.1145/3491101.3519784

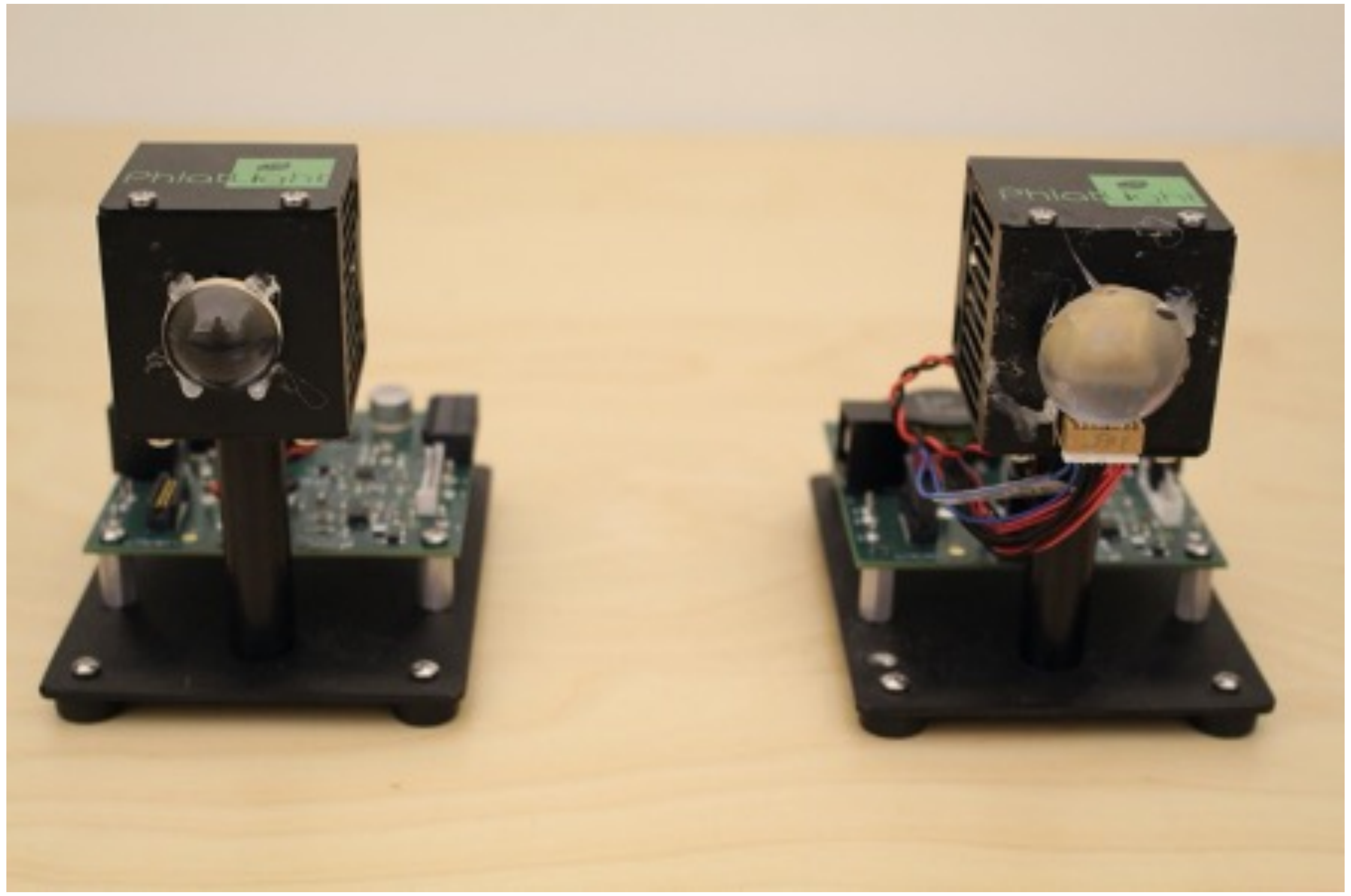
1 INTRODUCTION

Resin printing processes, such as stereolithography (SLA) and digital light processing (DLP), are some of the most commonly used technologies for 3D printing objects. These printing methods utilize a UV light source to cure a liquid photopolymer in a layer-wise man-ner until the entire object has been built. Compared to most other 3D printing methods, resin-based processes are able to produce parts with finer details, a higher dimensional accuracy and improved

Texture transfer speed

The stronger the projector, the faster the reprogramming

Saturation time: 1min

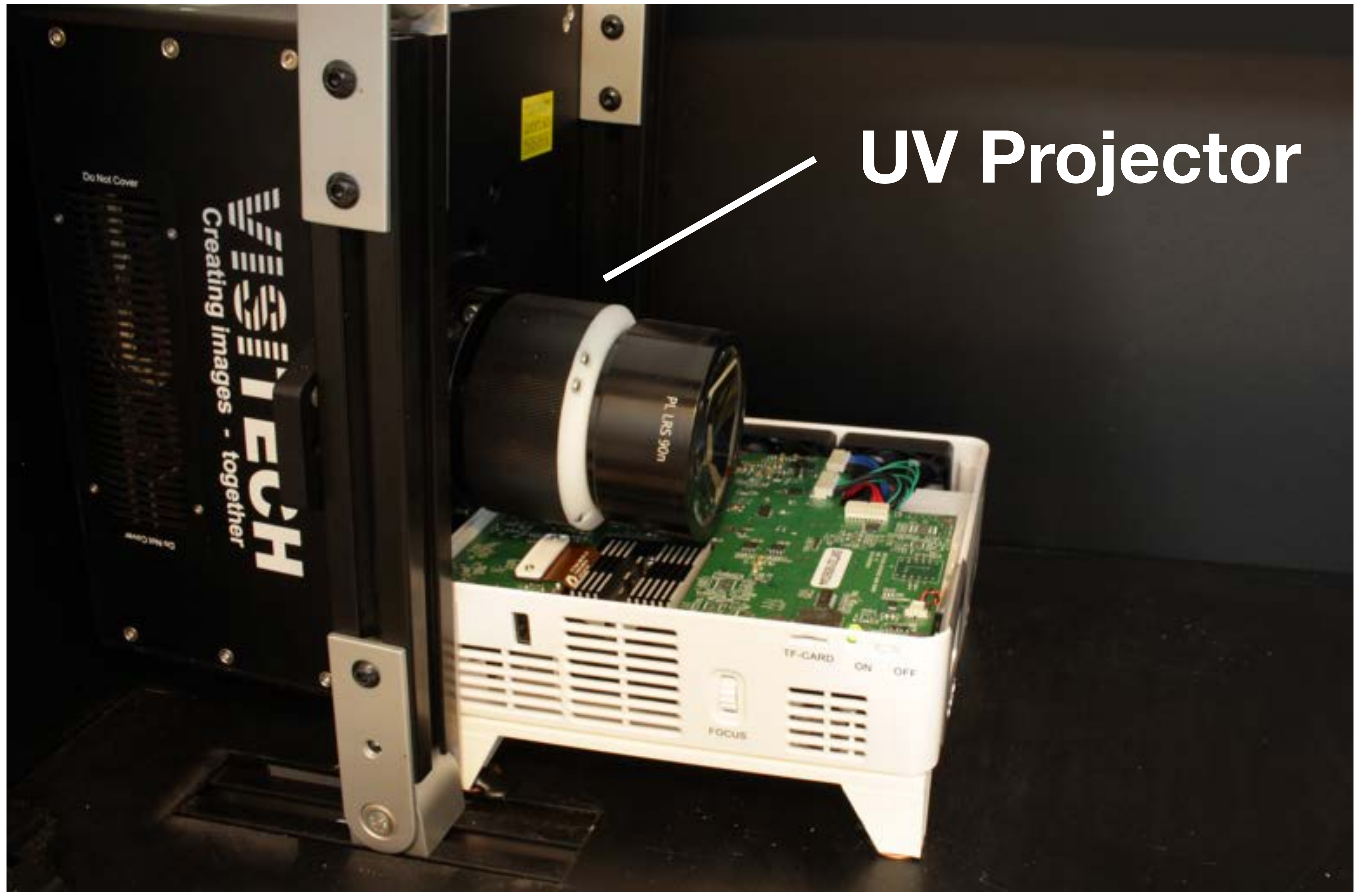


Saturation time: 30 seconds

Fast Previews in 60 seconds

In Grayscale

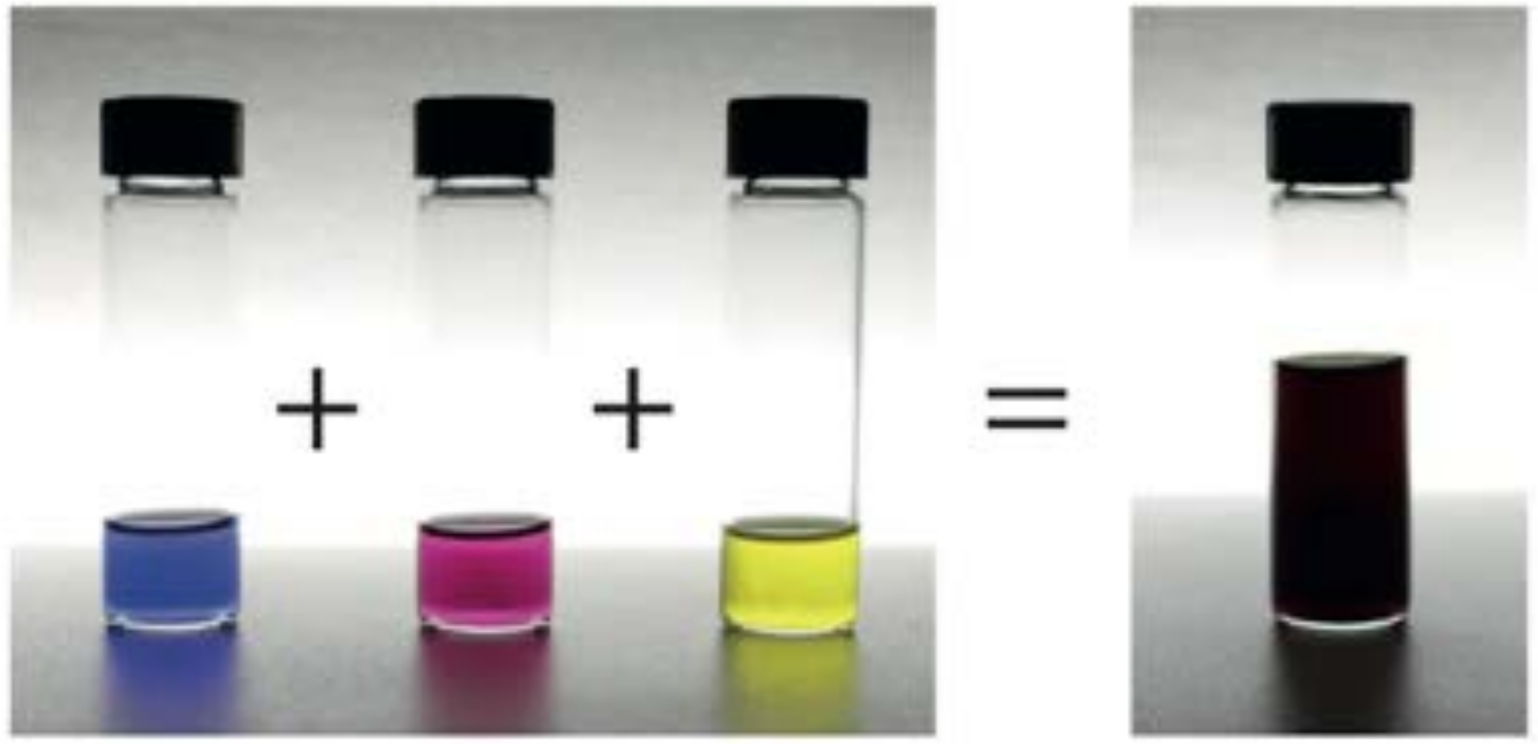
Wessely et al., ChromoUpdate, ACM CHI’21



Hardware Setup

photochromic
phone-case

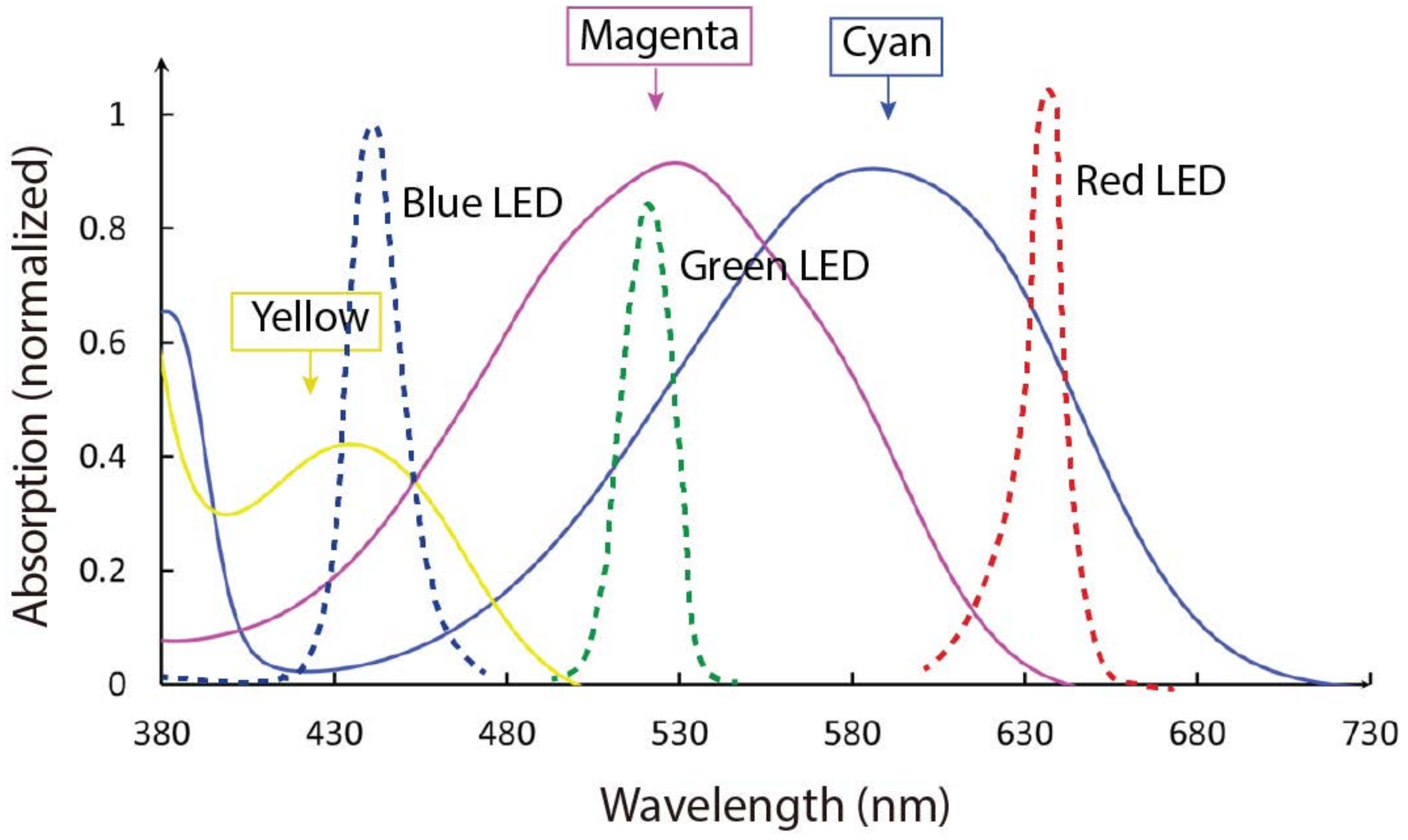
Summary



Reprogrammable Multicolor Ink

Using photochromic dyes

$$\min_{t} F(t) = (C(t) - B)^2$$



Computational model

Controlling individual saturation levels

Coating & Hardware System

For automatic reprogramming

How can we embed computing seamlessly into **our environment**?

Sprayable User Interfaces: Prototyping Large-Scale Interactive Surfaces with Sensors and Displays

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Isabel P.S. Qamar[12], **Mike Fraser**[3], **Anne Roudaut**[2], **Stefanie Mueller**[1]

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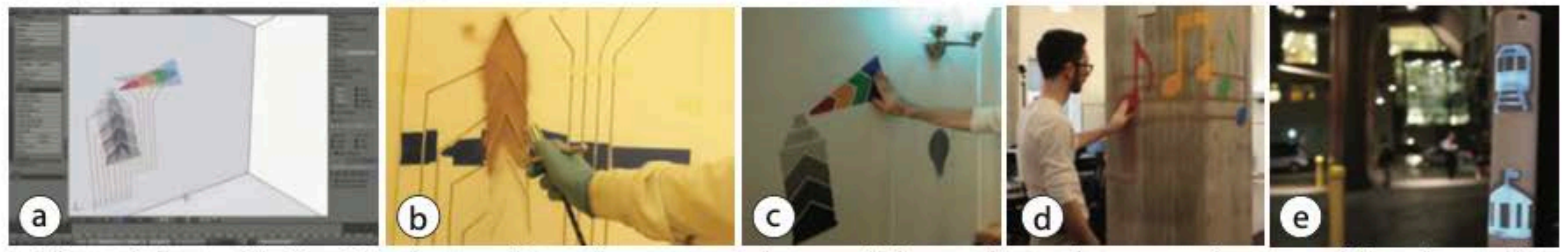

Figure 1. Sprayable User Interfaces enable makers to create large-scale interactive surfaces on various materials and curved geometries. After designing an interactive artwork (a), our tool supports their fabrication with auto-generated stencils (b) enabling novel user interfaces that cover entire rooms (c), integrate in interactive architecture (d), and smart cities (e).

ABSTRACT

We present Sprayable User Interfaces: room-sized interactive surfaces that contain sensor and display elements created by airbrushing functional inks. Since airbrushing is inherently mobile, designers can create large-scale user interfaces on complex 3D geometries where existing stationary fabrication methods fail.

To enable Sprayable User Interfaces, we developed a novel design and fabrication pipeline that takes a desired user interface layout as input and automatically generates stencils for airbrushing the layout onto a physical surface. After fabricating stencils from cardboard or projecting stencils digitally, designers spray each layer with an airbrush, attach a microcontroller to the user interface, and the interface is ready to be used.

Our technical evaluation shows that Sprayable User Interfaces work on various geometries and surface materials, such as porous stone and rough wood. We demonstrate our system with several application examples including interactive smart home applications on a wall and a soft leather sofa, an interactive smart city application, and interactive architecture in public office spaces.

Author Keywords

Spraying; fabrication; printed electronics; ubiquitous computing; airbrush

CSS Concepts

• **Human-centered computing~Human computer interaction (HCI)**; *Human-centered computing*

INTRODUCTION

Since the early 1990s, Human-Computer Interaction researchers have envisioned a world in which digital user interfaces are seamlessly integrated with the physical environment until the two are indistinguishable from one another *(Computer of the 21st century* [29]).

One of the greatest challenges in enabling this future is the integration of sensors and display elements with the physical environment, since the fabrication of interactive surfaces requires many design considerations, including how to adhere the elements to different materials and how to apply them onto irregular surface geometries in a manner accessible to novice users.

Over the last few years, novel fabrication methods have been developed that enable the fabrication of displays and sensors using inkjet- and screen-printing (*PrintScreen* [19]) as well as hydrographics (*ObjectSkin* [6]). However, all of these methods are limited to small-scale geometries, i.e. they are bound by the volume of the fabricating device, such as the size of the printer, the area of the screen-printing net, or the size of the hydrographic bath.

In this paper, we explore how to make large-scale user interfaces using spraying as the fabrication method. Unlike many existing techniques, such as 3D printing, screen printing or inkjet printing, spraying is not bound to a specific volume and, as often demonstrated by graffiti artwork, can create output that covers entire walls and even building facades. In addition, since spraying is a non-contact method, it works well on various surface textures (wallpaper, concrete, wood, bathroom tiles) and surface geometries, such as those with

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ProtoSpray: Combining 3D Printing and Spraying to Create Interactive Displays with Arbitrary Shapes

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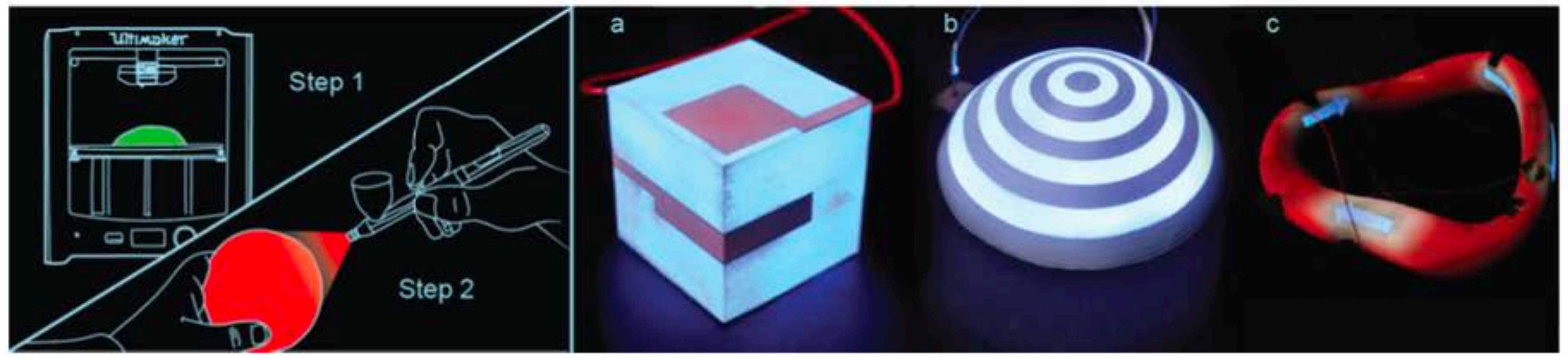

Figure 1. ProtoSpray is the first fabrication technique that combines 3D printing with spray coating to create interactive displays of arbitrary shapes. It uses mixed material printing of electrodes to create solid objects which are sprayed with layers of electroluminescent ink. Our prototypes (three of them shown (a-c)) demonstrate how ProtoSpray enables the creation of displays with complex curvatures, going further than any work done before.

ABSTRACT

ProtoSpray is a fabrication method that combines 3D printing and spray coating, to create interactive displays of arbitrary shapes. Our approach makes novel use of 3D printed conductive channels to create base electrodes on 3D shapes. This is then combined with spraying active materials to produce illumination. We demonstrate the feasibility and benefits of this combined approach in 6 evaluations exploring different shaped topologies. We analyze factors such as spray orientations, surface topologies and printer resolutions, to discuss how spray nozzles can be integrated into traditional 3D printers. We present a series of ProtoSprayed objects demonstrating how our technique goes beyond existing fabrication techniques by allowing creation of displays on objects with curvatures as complex as a Mobius strip. Our work provides a platform to empower makers to use displays as a fabrication material.

Author Keywords

3D Printing, Spraying, Display, Electroluminescence, Rapid Prototyping, Fabrication

CCS Concepts

•**Human-centered computing** → **Touch screens;**

INTRODUCTION

3D printers have revolutionised the way we create interactive objects, allowing non-experts to prototype industrial quality products at home. Beyond conventional plastic printing, it is even possible to print functional objects such as capacitive touch sensors using conductive filament [43], speakers via printed piezoelectric material [20], objects conveying light via embedded optical fibers [9, 53] and actuators printed in dielectric elastomer [16].

Despite the abundance of new techniques, 3D printed displays are largely unexplored. Existing machines for printed electronics are confined to specialized labs as they rely on complex mechanisms beyond the scientific and financial reach of typical fabrication spaces and end users, such as nano-scale printing techniques [6] or Aerosol Jet approaches [44]. Consequently it is limiting for the design community to experiment with new forms of displays as they must rely on using projection [2, 7, 40], or off-the-shelf display tessellations [4, 27].

Electroluminescent (EL) ink has gained popularity among the HCI community as a way to address this issue and explore new approaches to display fabrication. Ink can be deposited using methods such as screen printing [34, 50, 52], spin-coating [3] or bar coating techniques [35]. However, these processes are limited to substrates with flat topologies and can thus produce a limited range of display shapes. Hydro-printing [15] has been demonstrated to have the potential to create displays on 3D objects but this has not been successfully shown beyond a single EL cell on a gently curved surface. The topologies of shapes that can be created is thus still limited.

However, creating complex topologies with EL material is challenging. The material cannot be deposited directly using domestic 3D printers because: (1) EL requires uniform deposition to avoid unpredictable electrical behaviour and short circuits [3]; (2) deposition needs to be in thinner layers, for energy efficiency, than commodity 3D printer resolution allows

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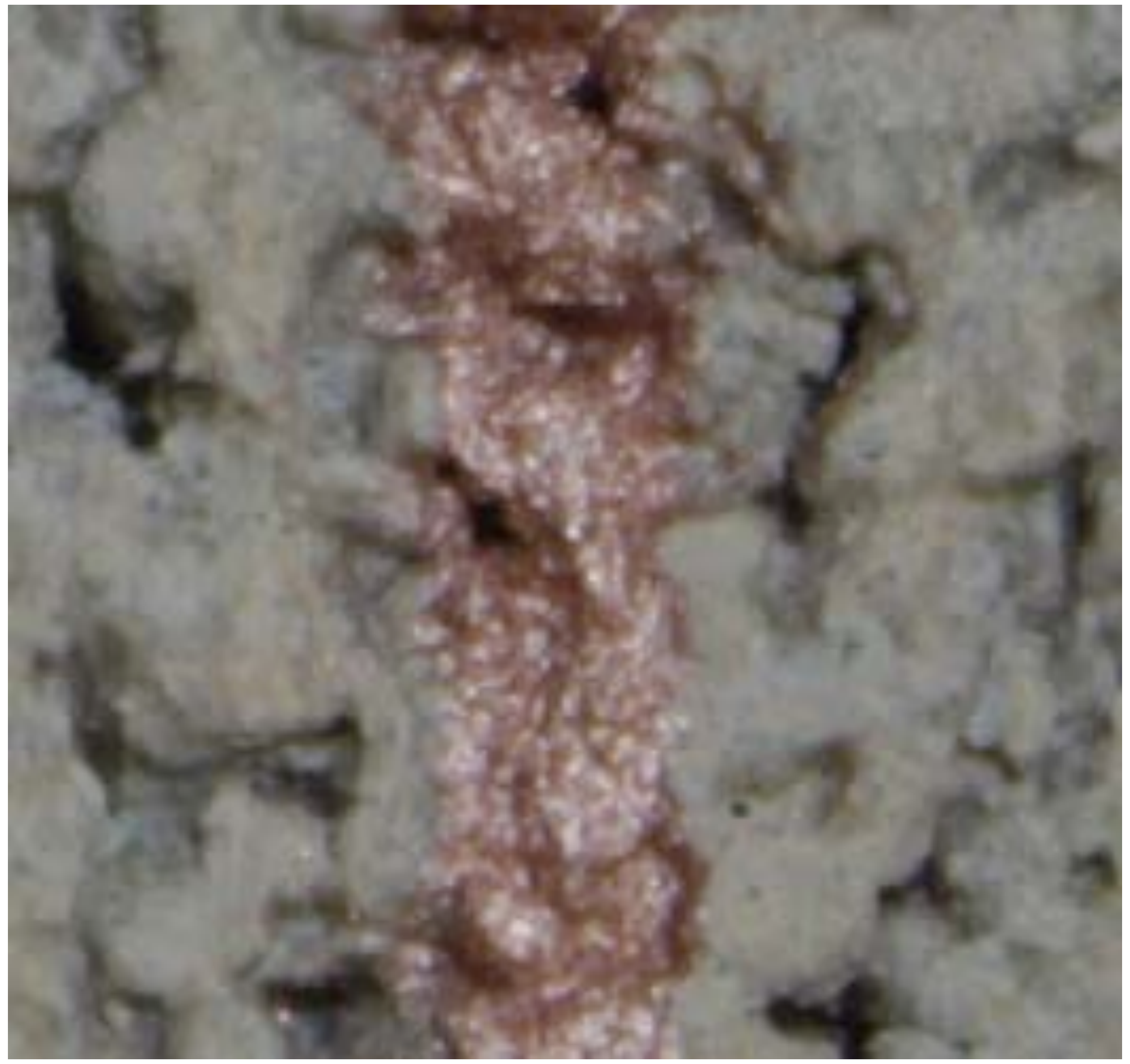
http://dx.doi.org/10.1145/3313831.3376543

Challenges for Large-Scale User Interfaces

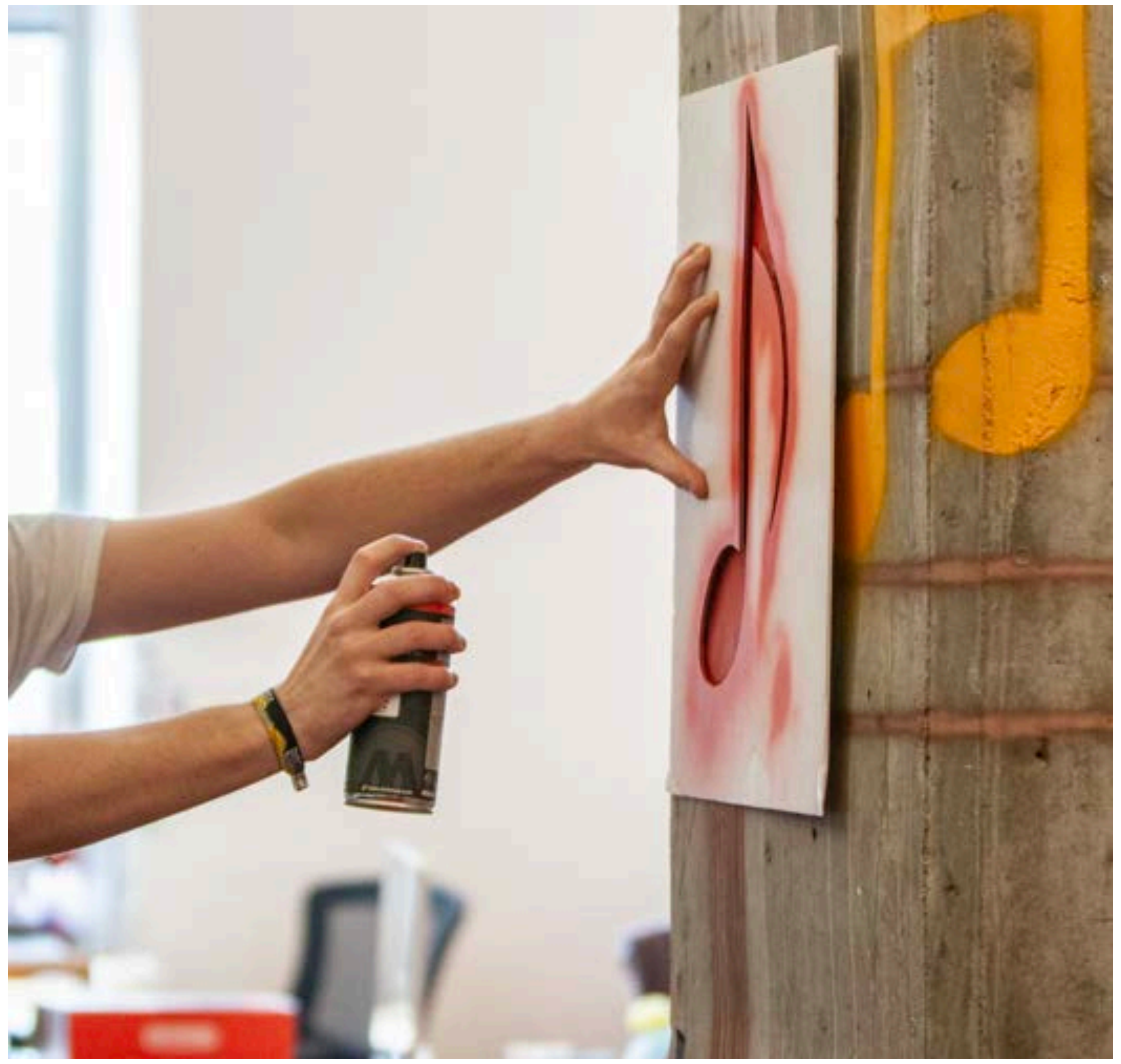
Rough Materials

Size Limitations

Challenges for Large-Scale User Interfaces



Spraying is contact-less

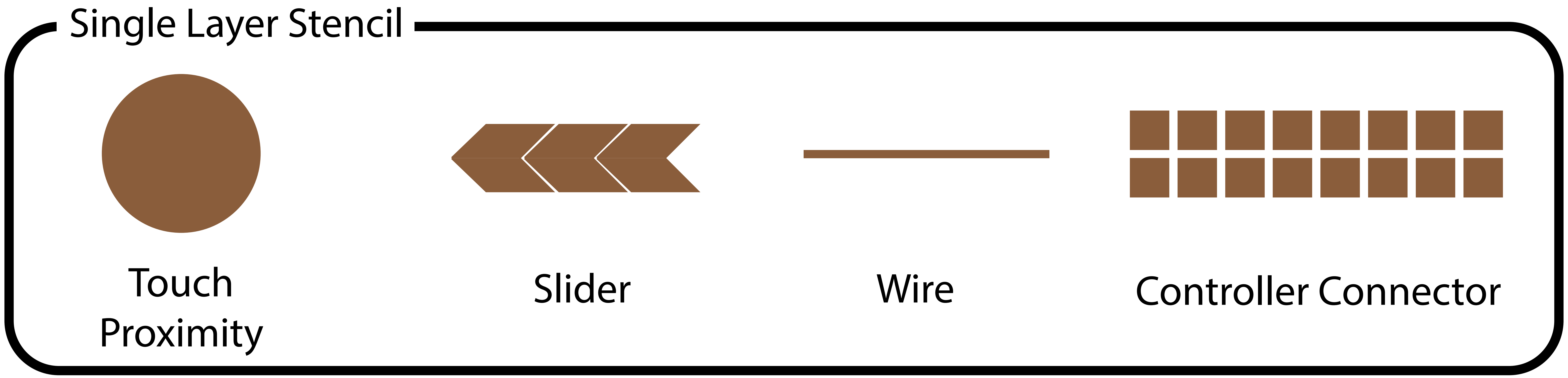


Spraying is not Limited in Size

Spraying Sensor and Displays

Copper

Clear Conductor (PEDOT:PSS)



Single Layer Stencil

Touch
Proximity

Slider

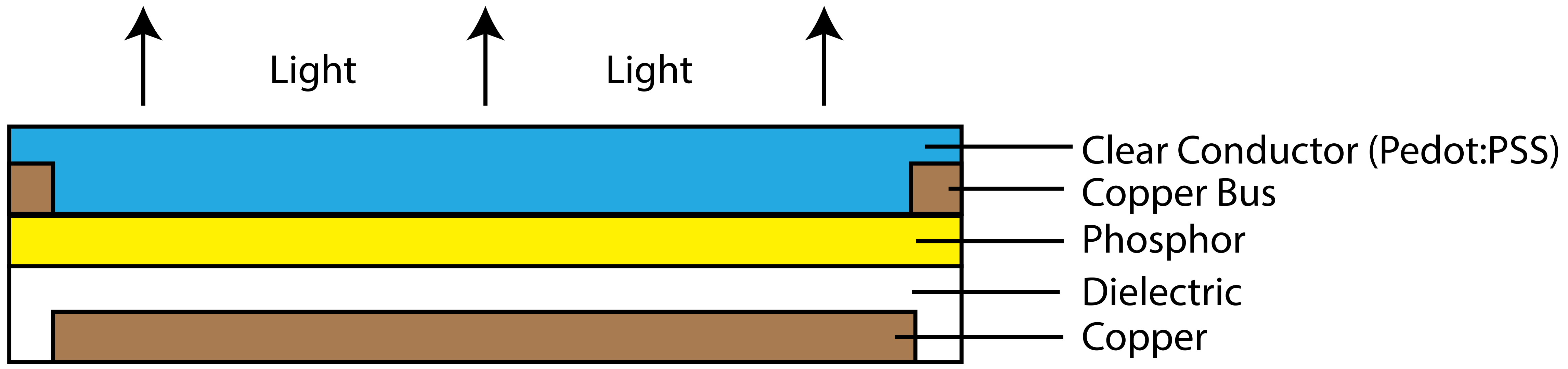
Wire

Controller Connector

Application Example: Interactive Furniture

We design the spraybale UI in Blender

Electroluminescent Displays



Light

Light

Clear Conductor (Pedot:PSS)

Copper Bus

Phosphor

Dielectric

Copper

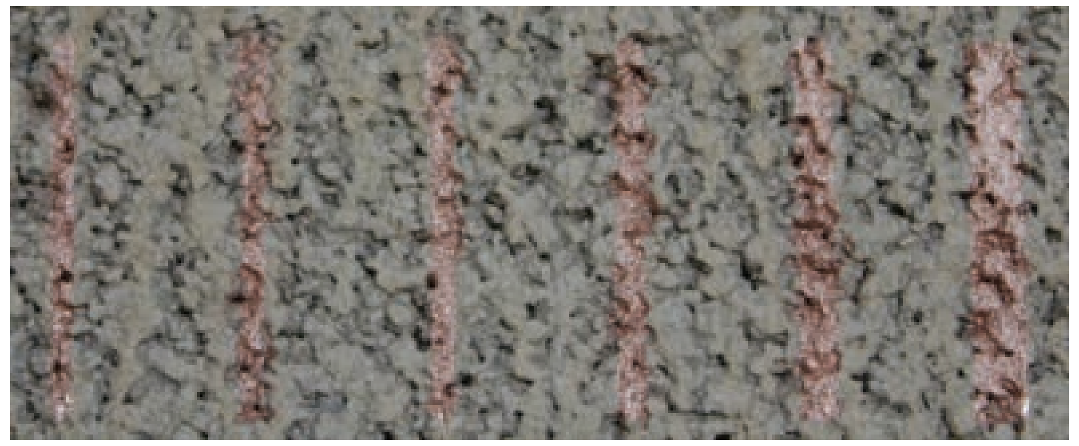
EL touch displays consist of 5 stacked layers:

Electroluminescent Touch Display

Technical Evaluation
On soft and rough materials

Conductivity

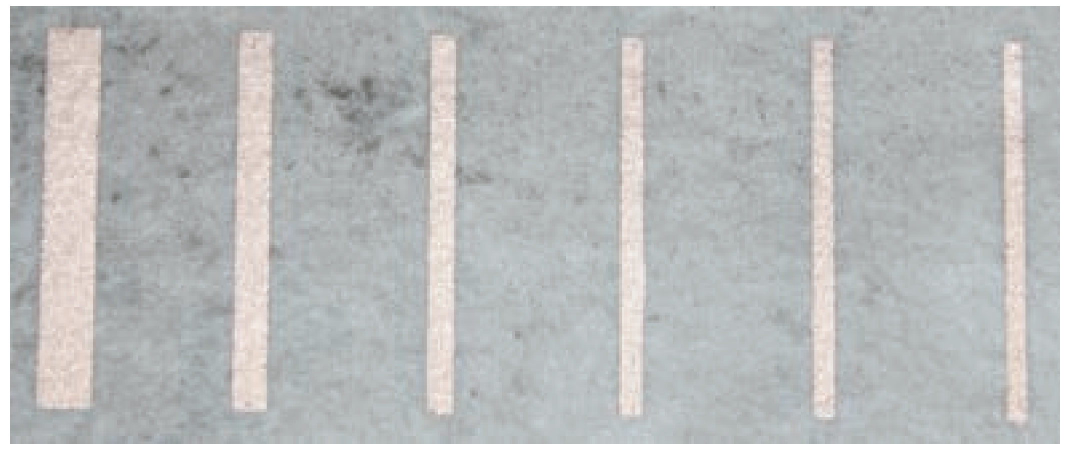
On different materials



Porous Stone

Organic Sponge

Smooth Marble

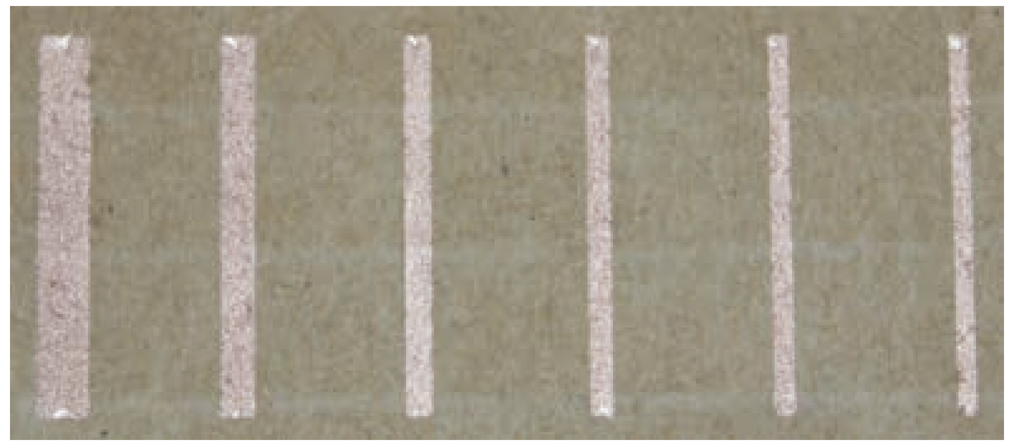


Rough Ceramic

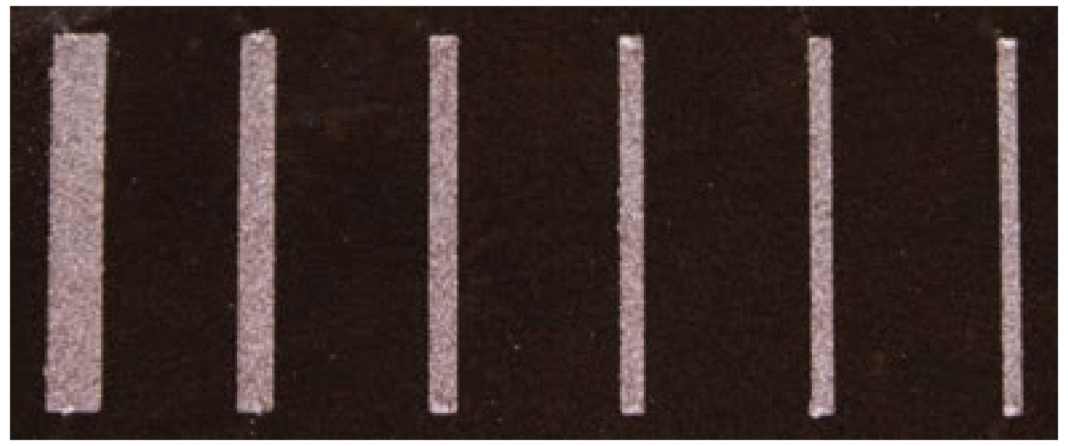
Rough Wood

PLA

Transparent PVC



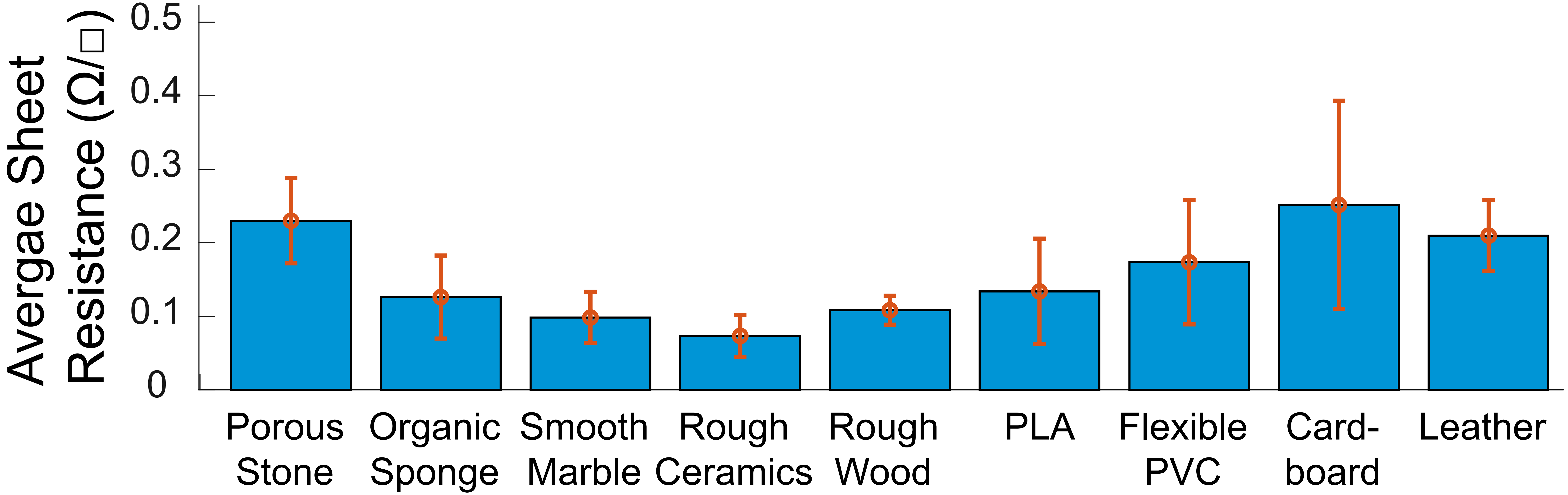
Cardboard



Leather

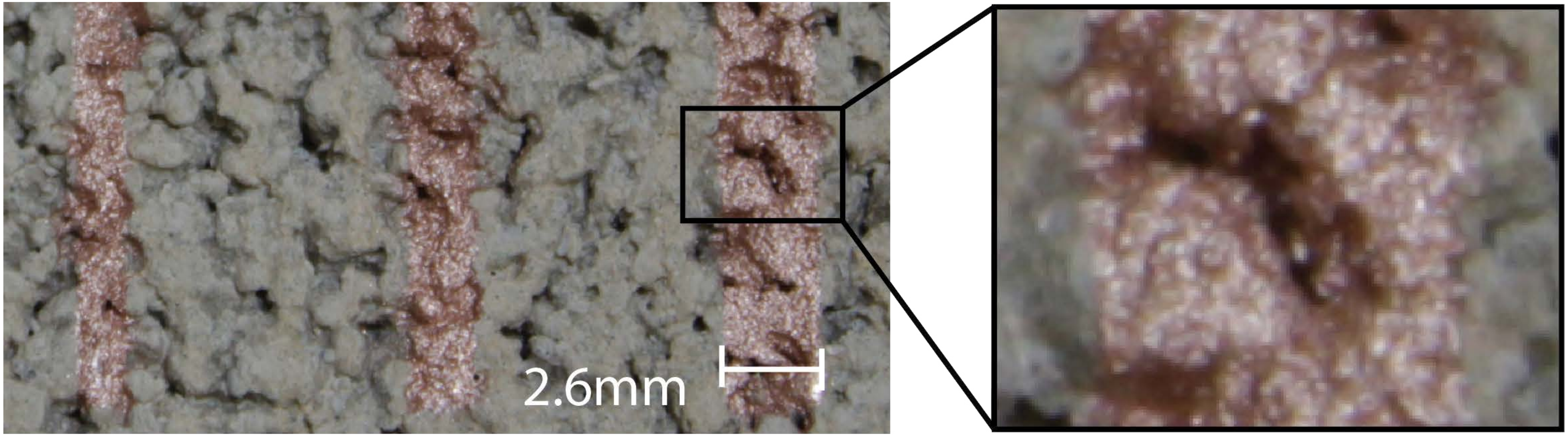
Conductivity

rough surfaces do not hinder conductivity



Conductivity

rough surfaces do not hinder conductivity



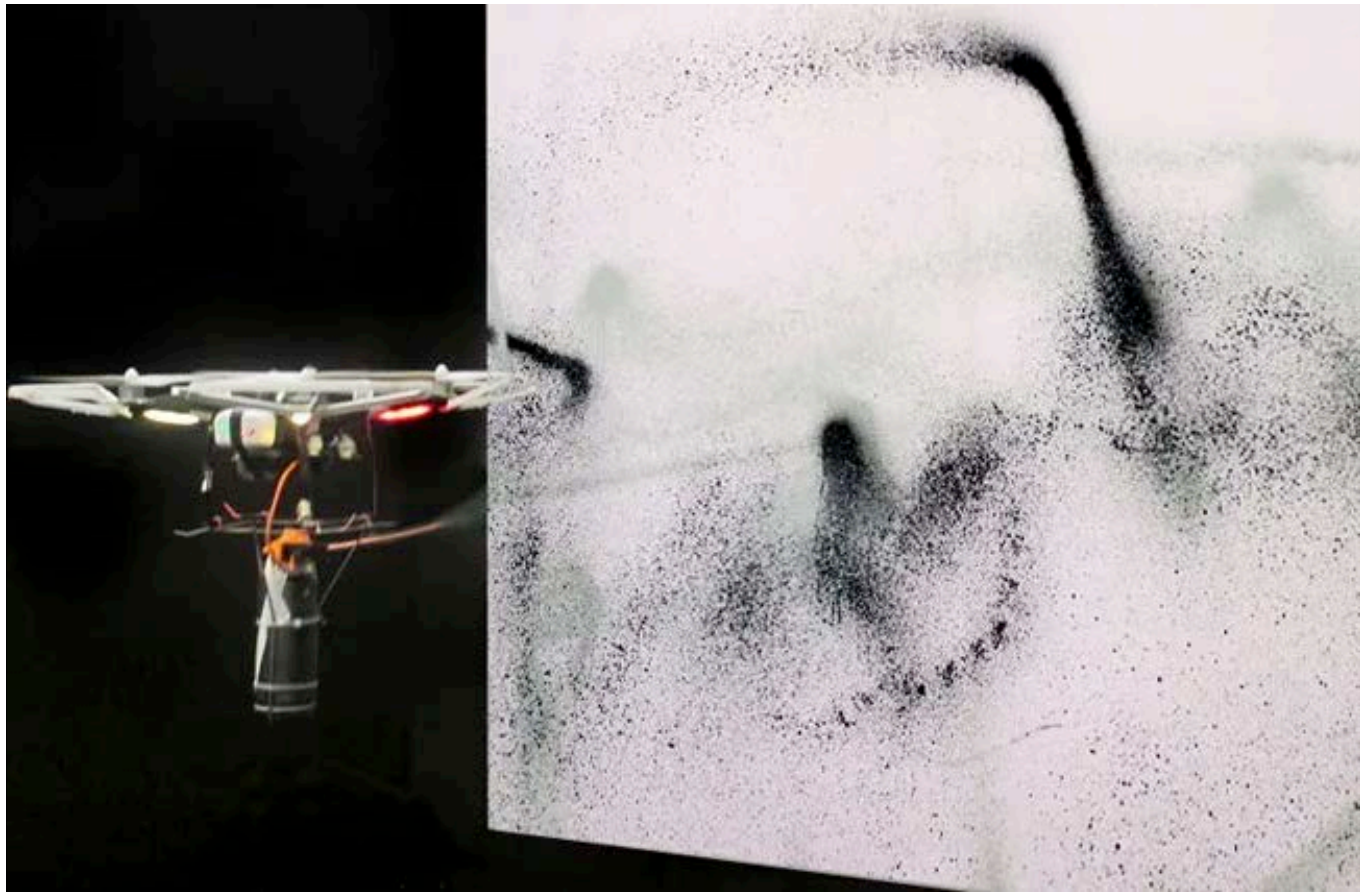
Porous stone

Sound on

Challenges and Opportunities

Interactive Architecture: Scaling it up to Buildings

Actuated panels
Control the appearance of the buildings



Source: Katsu

How can we integrate computing seamlessly into **the human body**?

MouthIO

Fabricating Customizable Oral User Interfaces with Integrated Sensing and Actuation

Yijing Jiang, Julia Kleinau, Till Max Eckroth,
Eve Hoggan, Stefanie Mueller, Michael Wessely

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MouthIO: Fabricating Customizable Oral User Interfaces with Integrated Sensing and Actuation

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Figure 1: (a) MouthIO schematic. The oral interface consists of three components: (1) the 3D-printed brace that gets attached to the teeth, (2) the integrated flexible PCB with circuits, battery, microcontroller, and sensors, and (3) the PCB housing to water-proof encapsulate the electronics and make it bite-save. (b) Wearing a MouthIO interface integrating two capacitive touchpads that enable the detection of tongue tapping, serving as an assistive tool for users with motor impairment.

ABSTRACT

This paper introduces *MouthIO*, the first customizable intraoral user interface that can be equipped with various sensors and output components. *MouthIO* consists of an SLA-printed brace that houses a flexible PCB within a bite-proof enclosure positioned between the molar teeth and inner cheeks. Our *MouthIO* design and fabrication technique enables makers to customize the oral user interfaces in both form and function at low cost. All parts in contact with the oral cavity are made of bio-compatible materials to ensure safety, while the design takes into account both comfort and portability. We demonstrate *MouthIO* through three application examples ranging from beverage consumption monitoring, health monitoring, to assistive technology. Results from our full-day user study indicate high wearability and social acceptance levels, while our technical evaluation demonstrates the device's ability to withstand adult bite forces.

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https://doi.org/10.1145/3654777.3676443

CCS CONCEPTS

- **Human-centered computing → Interaction devices**; **Ubiquitous and mobile computing**.

KEYWORDS

Oral Interface, Wearable Computing, Fabrication, Flexible Circuits

ACM Reference Format:
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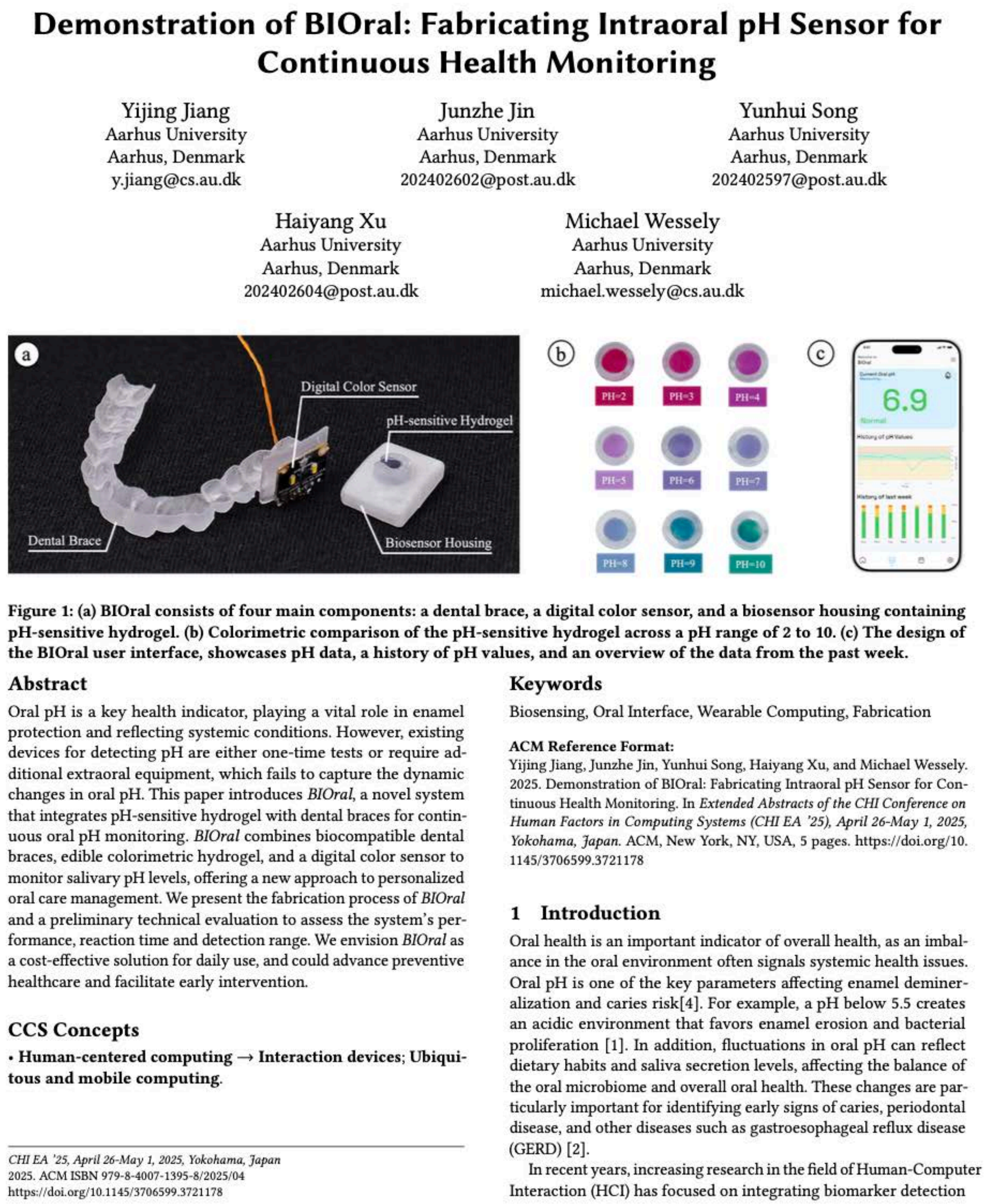
1 INTRODUCTION

Wearable electronics are widely used for health monitoring and to sense user interaction as they are readily available to capture input and often have continuous access to the user's bio-signals, such as the user's heart rate. However, most wearable devices are worn on the skin or integrated into textiles, while intraoral wearable technology that is worn inside the mouth is still rare.

Recent research has demonstrated that oral interfaces can provide a variety of discreet hands-free and eyes-free interactions and help improve the efficiency of multitasking [19, 38]. In addition, they

UIST'24



Demonstration of BIOral: Fabricating Intraoral pH Sensor for Continuous Health Monitoring

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Figure 1: (a) BIOral consists of four main components: a dental brace, a digital color sensor, and a biosensor housing containing pH-sensitive hydrogel. (b) Colorimetric comparison of the pH-sensitive hydrogel across a pH range of 2 to 10. (c) The design of the BIOral user interface, showcases pH data, a history of pH values, and an overview of the data from the past week.

Abstract

Oral pH is a key health indicator, playing a vital role in enamel protection and reflecting systemic conditions. However, existing devices for detecting pH are either one-time tests or require additional extraoral equipment, which fails to capture the dynamic changes in oral pH. This paper introduces *BIOral*, a novel system that integrates pH-sensitive hydrogel with dental braces for continuous oral pH monitoring. *BIOral* combines biocompatible dental braces, edible colorimetric hydrogel, and a digital color sensor to monitor salivary pH levels, offering a new approach to personalized oral care management. We present the fabrication process of *BIOral* and a preliminary technical evaluation to assess the system's performance, reaction time and detection range. We envision *BIOral* as a cost-effective solution for daily use, and could advance preventive healthcare and facilitate early intervention.

CCS Concepts

- **Human-centered computing → Interaction devices**; **Ubiquitous and mobile computing**.

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2025. ACM ISBN 979-8-4007-1395-8/2025/04
https://doi.org/10.1145/3706599.3721178

Keywords

Biosensing, Oral Interface, Wearable Computing, Fabrication

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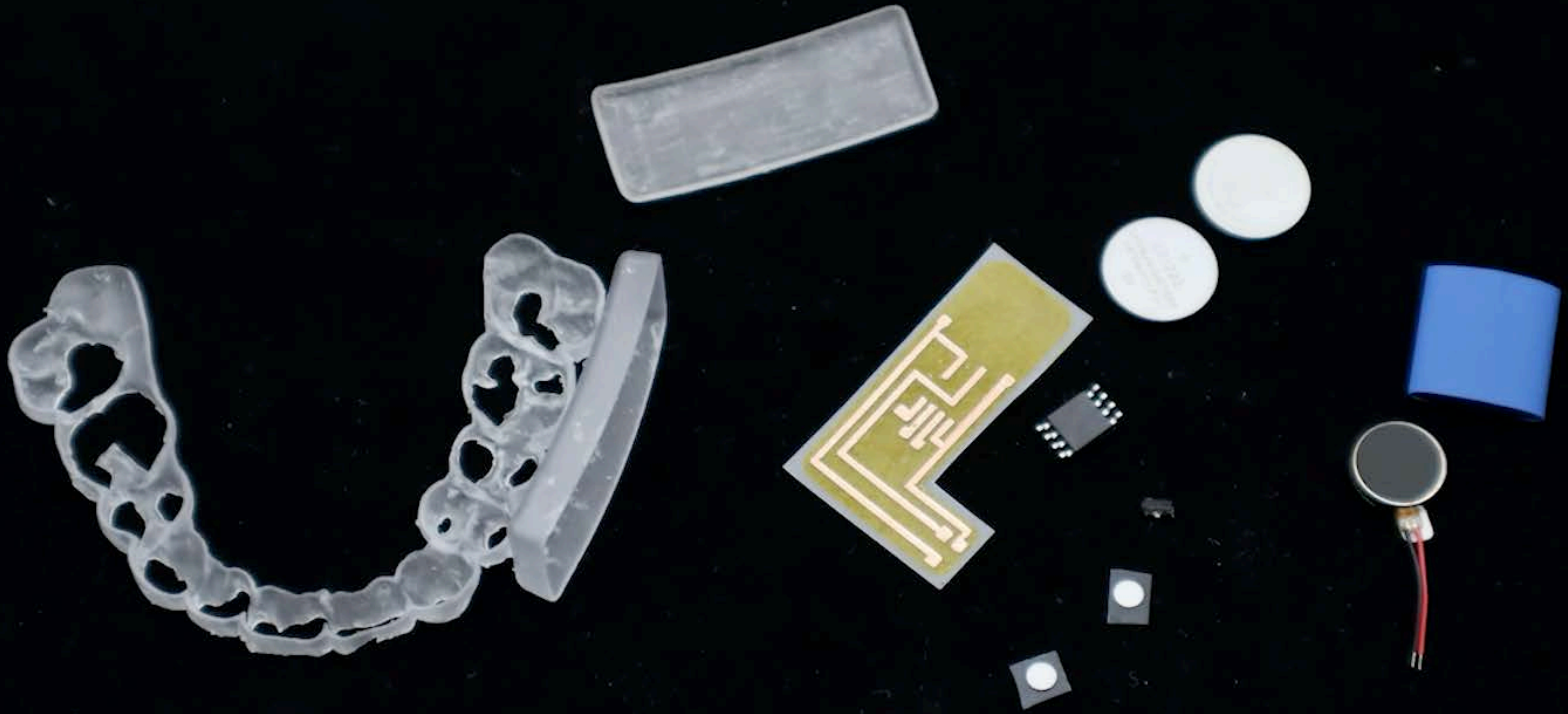
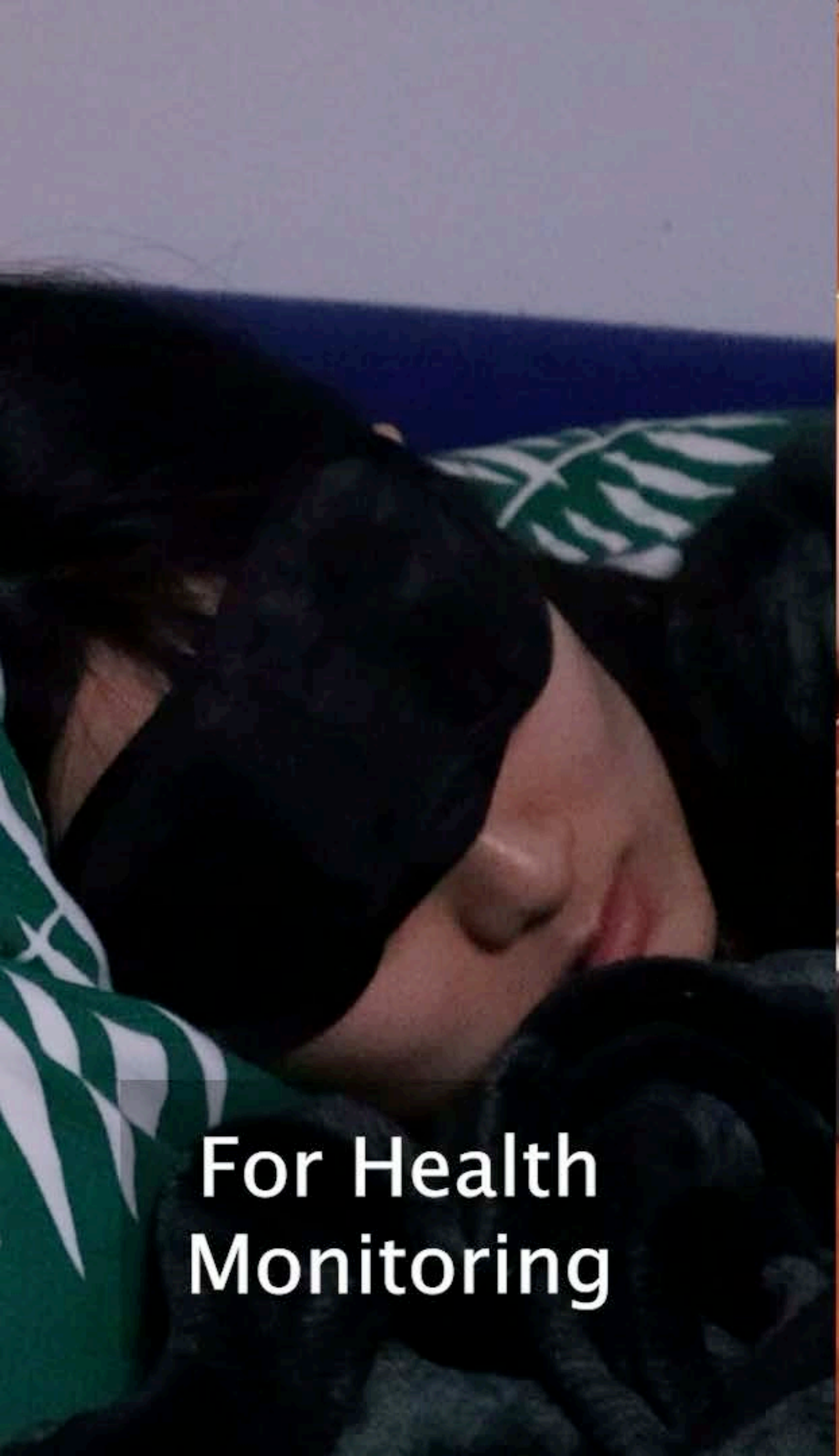
1 Introduction

Oral health is an important indicator of overall health, as an imbalance in the oral environment often signals systemic health issues. Oral pH is one of the key parameters affecting enamel demineralization and caries risk[4]. For example, a pH below 5.5 creates an acidic environment that favors enamel erosion and bacterial proliferation [1]. In addition, fluctuations in oral pH can reflect dietary habits and saliva secretion levels, affecting the balance of the oral microbiome and overall oral health. These changes are particularly important for identifying early signs of caries, periodontal disease, and other diseases such as gastroesophageal reflux disease (GERD) [2].

In recent years, increasing research in the field of Human-Computer Interaction (HCI) has focused on integrating biomarker detection

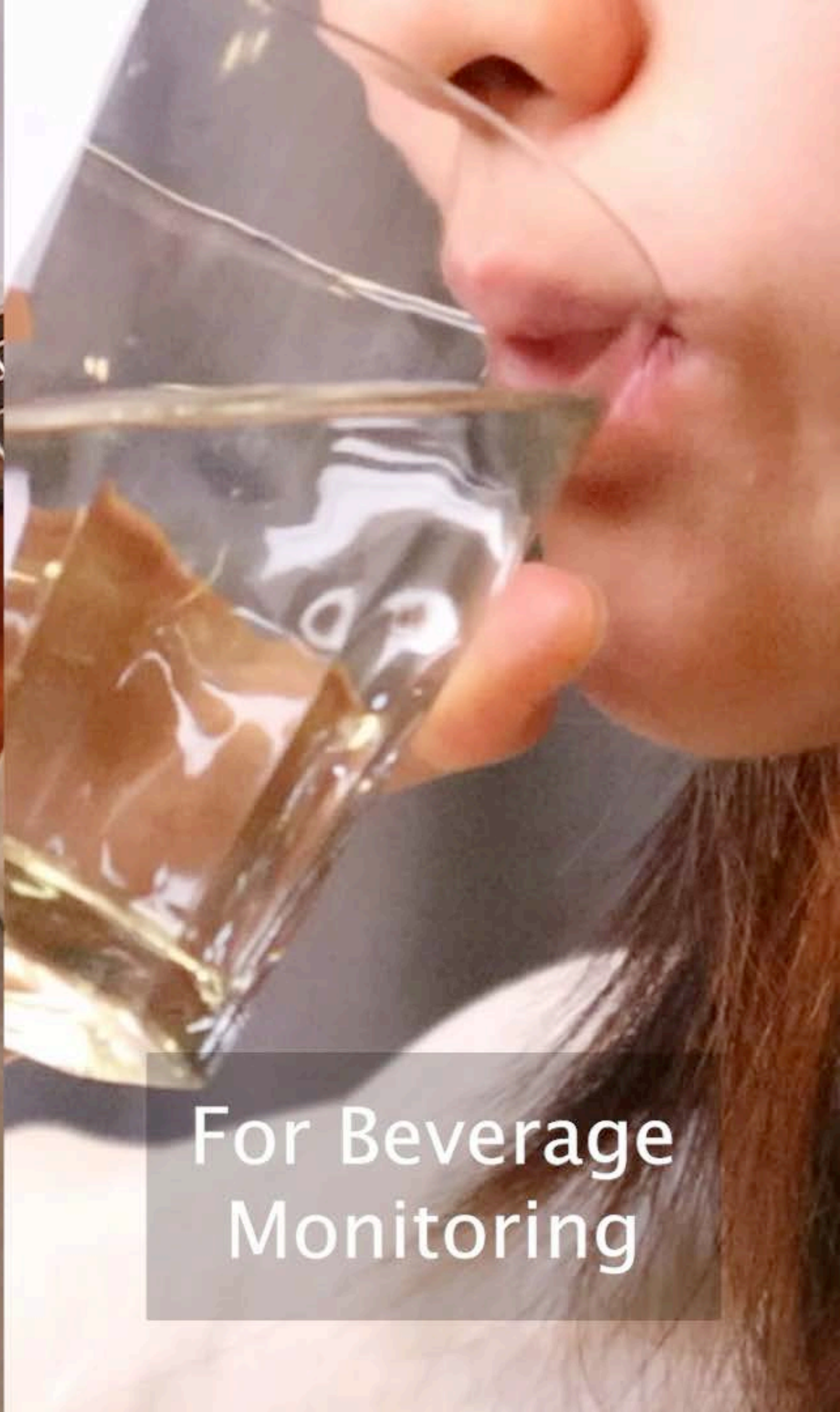
CHI'25 Demo





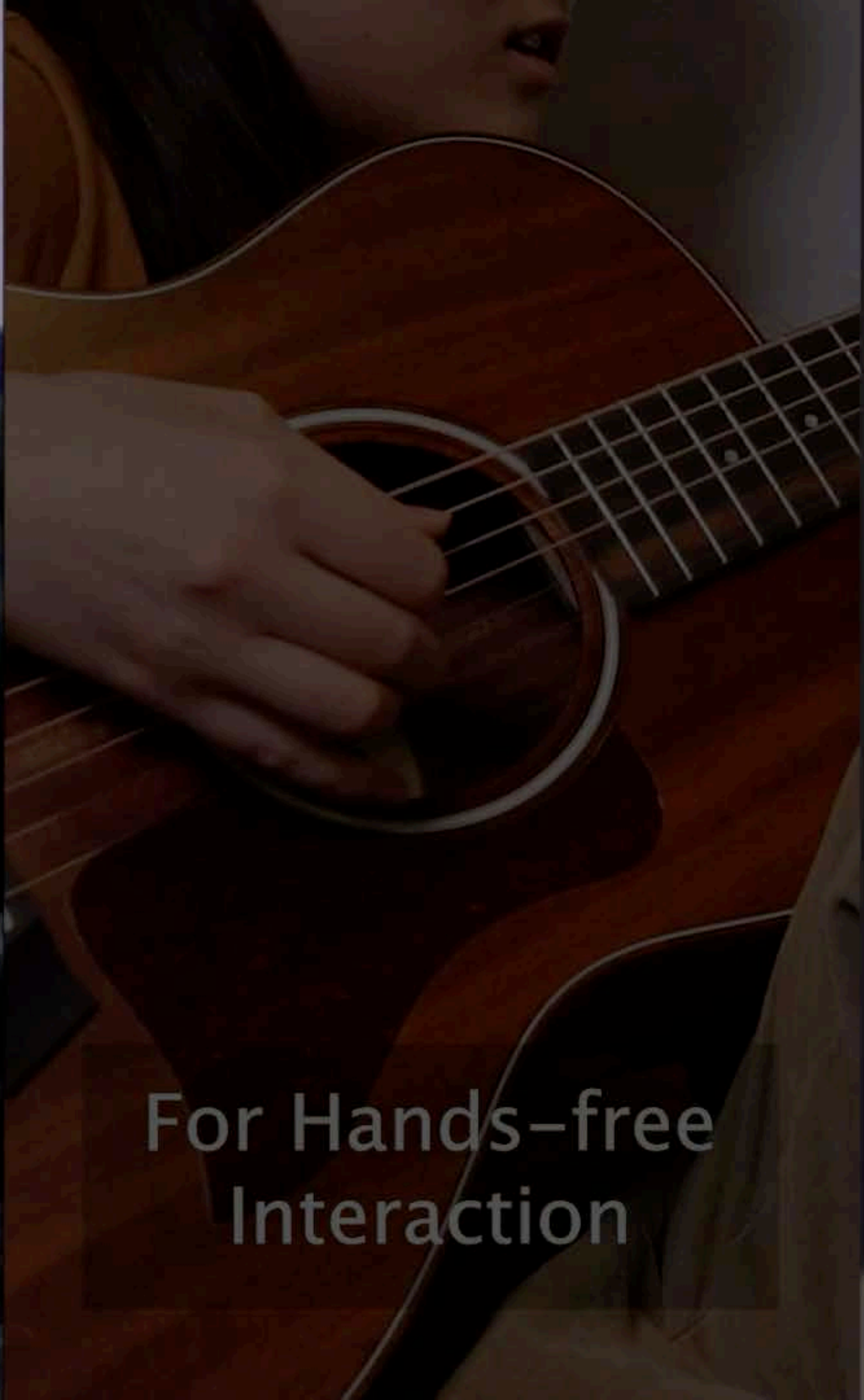
For Health Monitoring

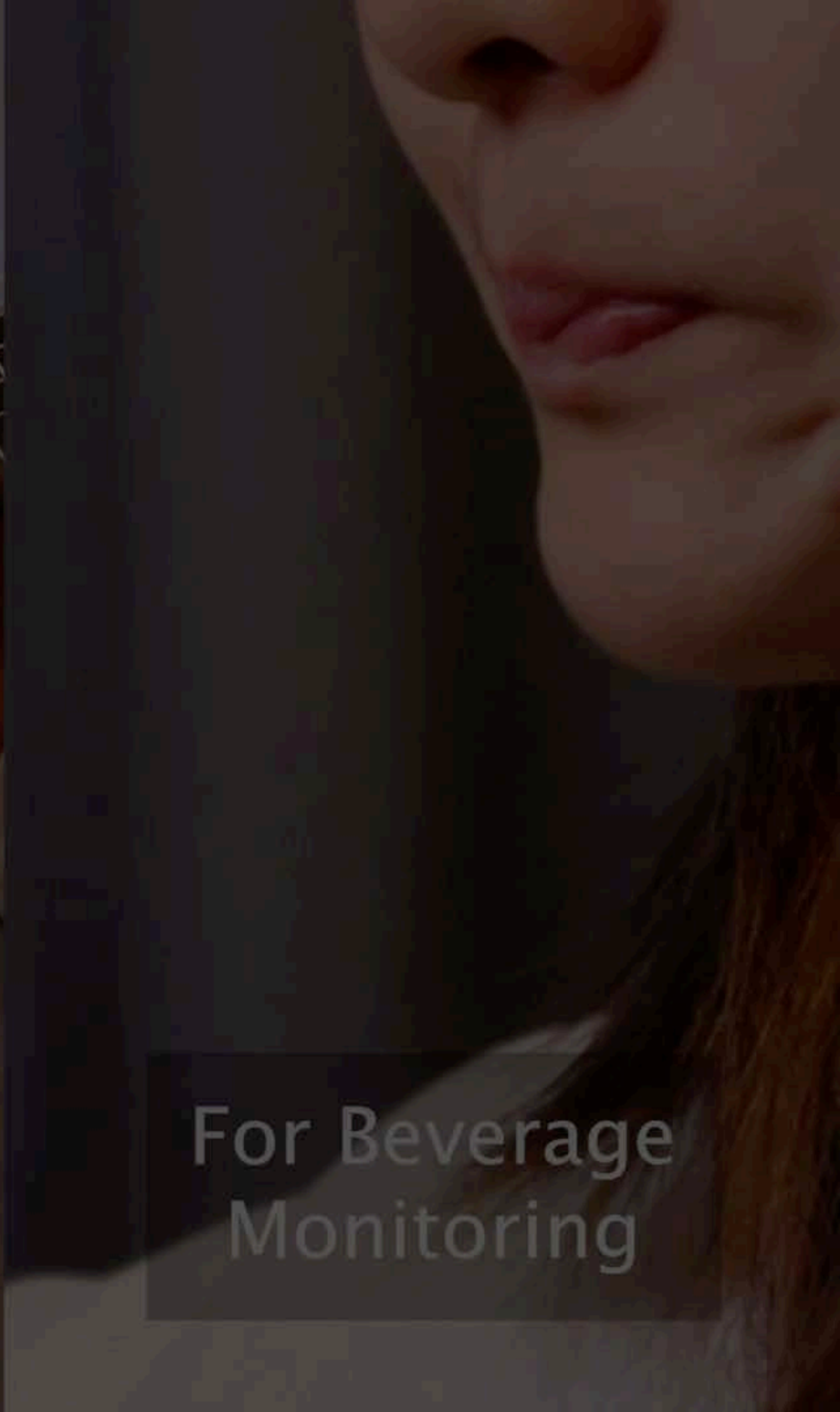
For Hands-free Interaction



For Beverage Monitoring

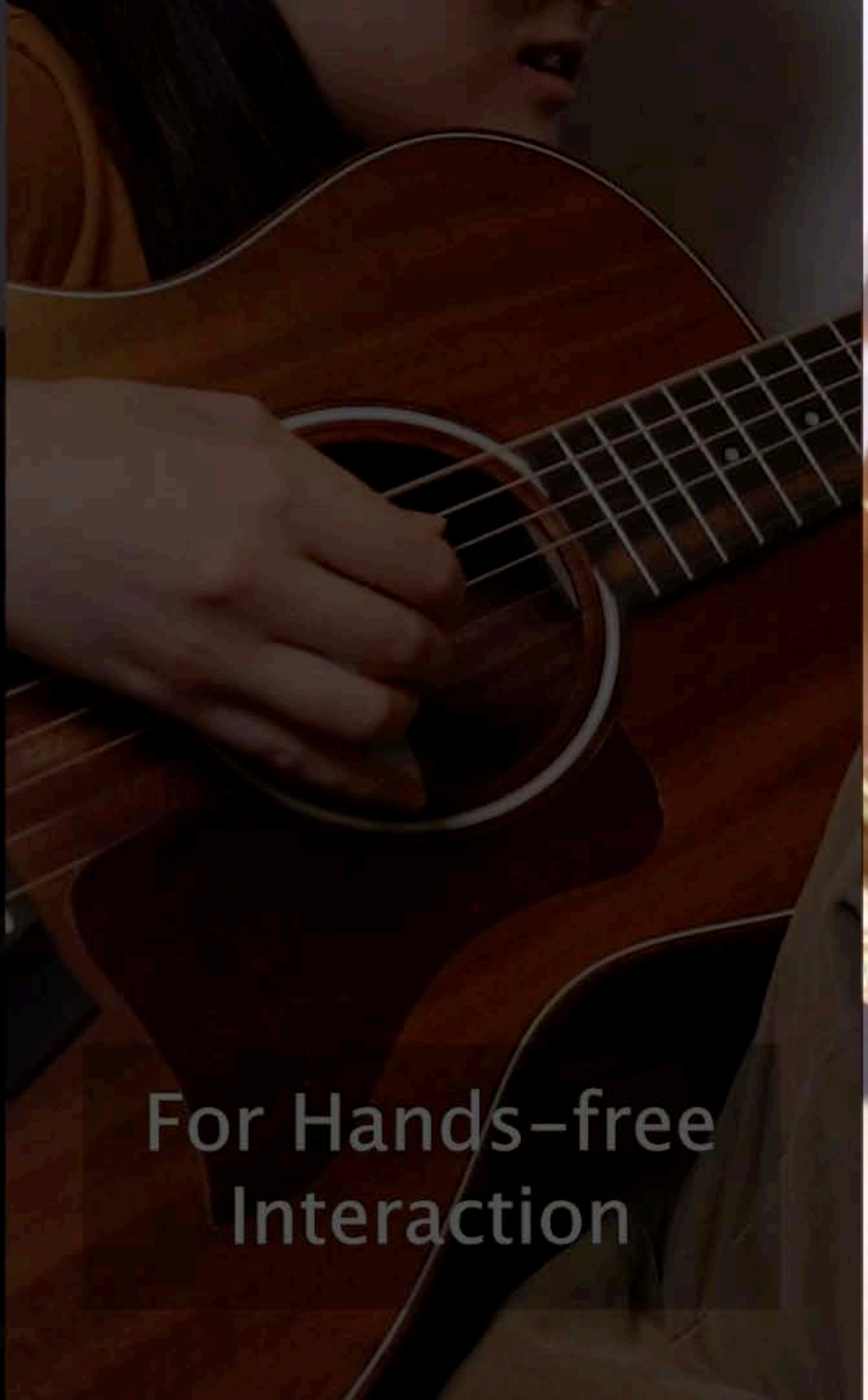

For Health Monitoring


For Hands-free Interaction

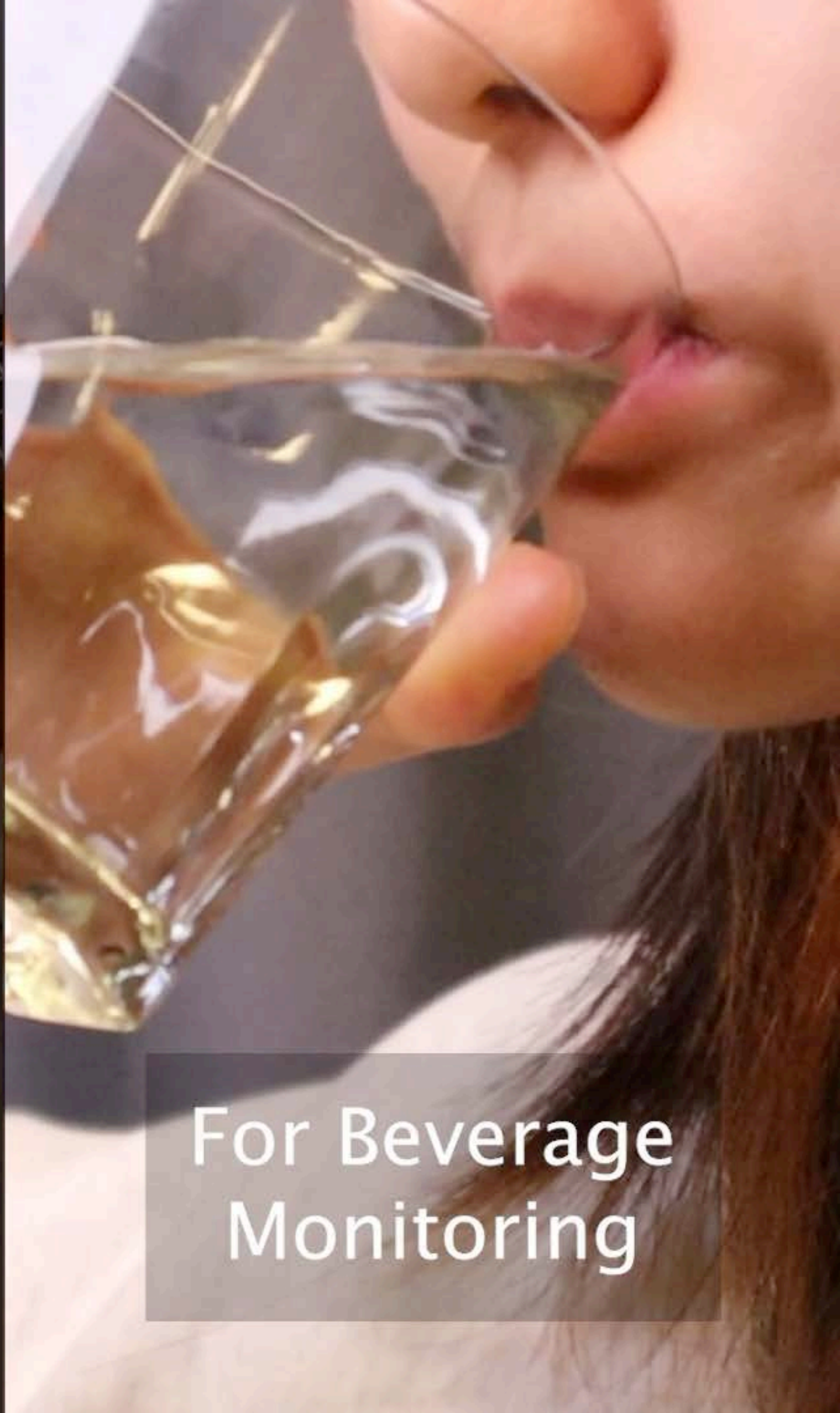

For Beverage Monitoring

Using tongue tapping to turn the page while playing guitar

For Health Monitoring



For Hands-free Interaction



For Beverage Monitoring

Design Principles

Safety

- Bio-compatible Material
- Bite-proof Design
- Water-contact indicators

Comfort

- Miniaturizing Electronics
- Open-Bite Design

Mobility

- Fully-Functional as is
- Wireless Charging and Communication

Accessible Fabrication

- Commercially available materials
- Inexpensive (~$20 per brace)

Wide Range of Functionality

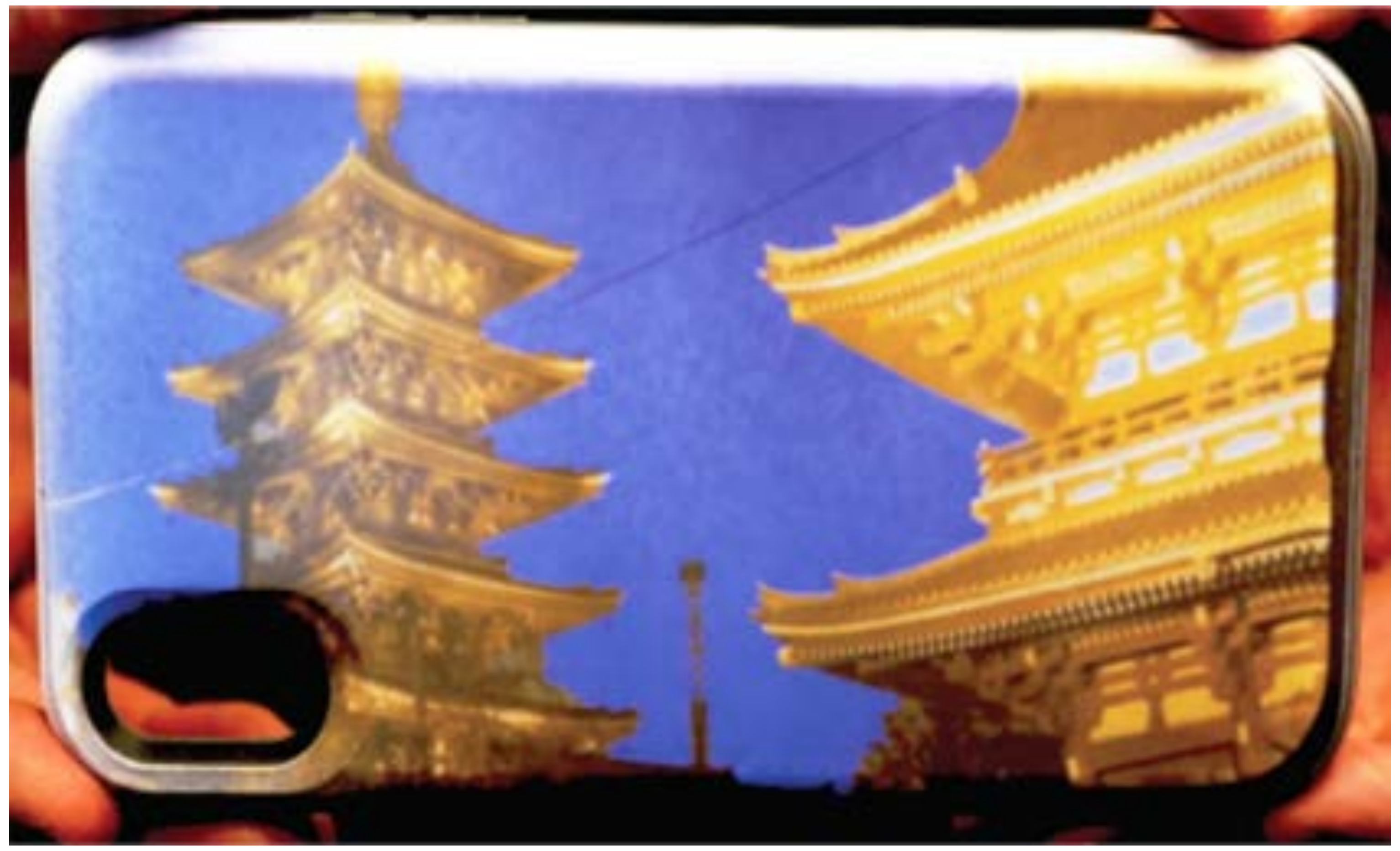
- Supports custom PCB designs
- Wide range of sensors and output components available

Let’s step back for a moment

Computing has revolutionized how we interact with **digital data**

However, these capabilities are difficult to apply to **physical matter**…

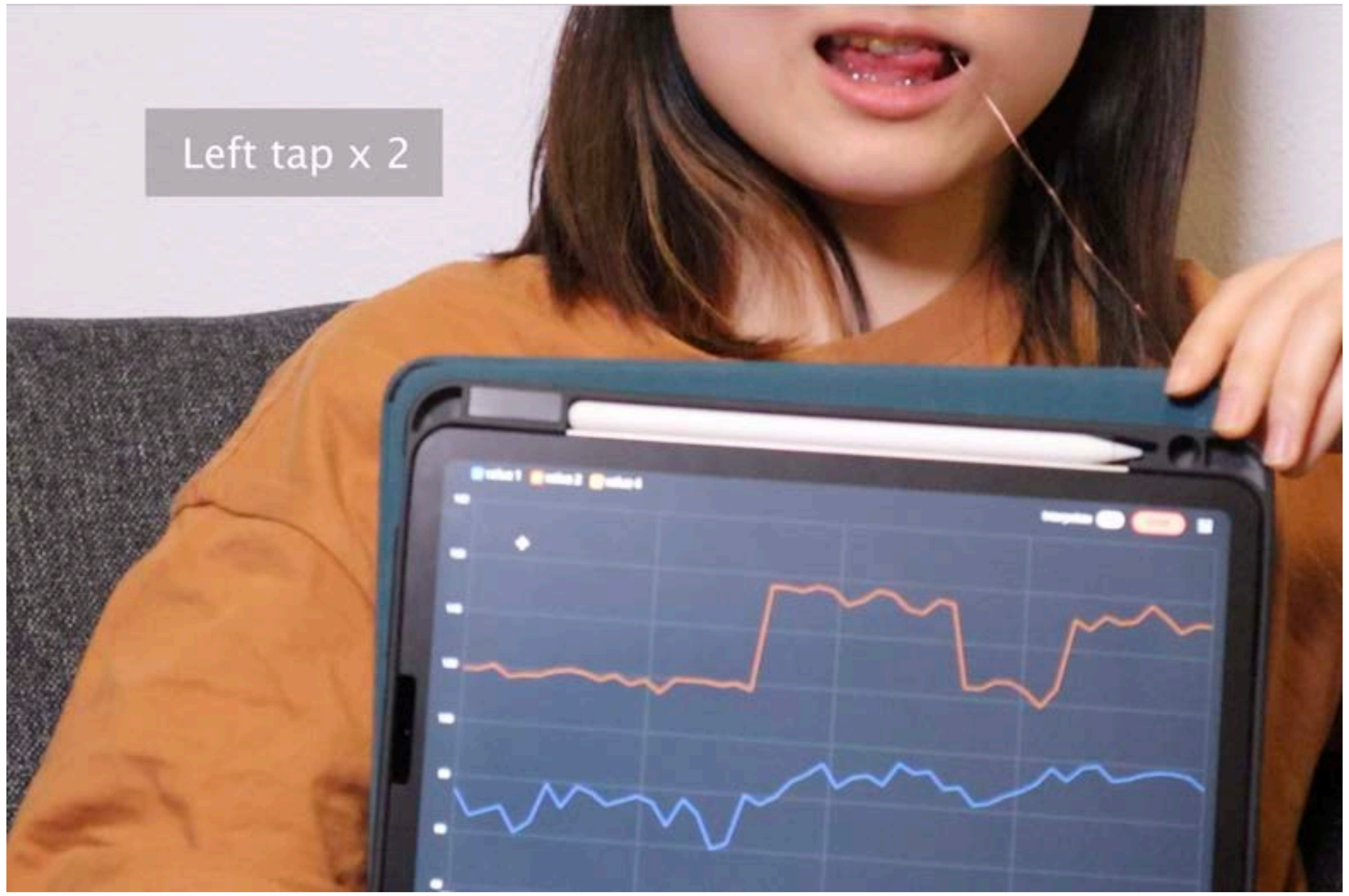
#1 How can we integrate computing into **everyday objects**?



**the same phone case
in all three images**

#2 How can we integrate computing into **our environment**?

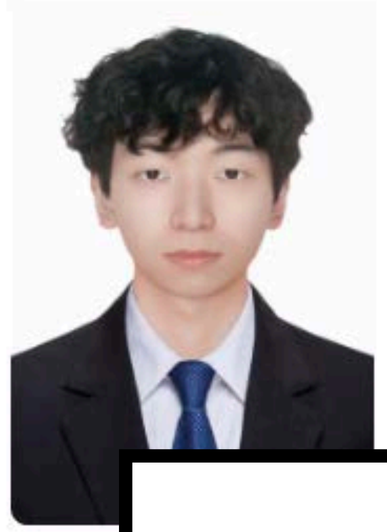
#3 How can we integrate computing to **the human body?**



Thanks to my awesome team

Yijing Jiang

PhD Student



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Jeff Pultz Gottfredsen

Master Student

Till Max Eckroth

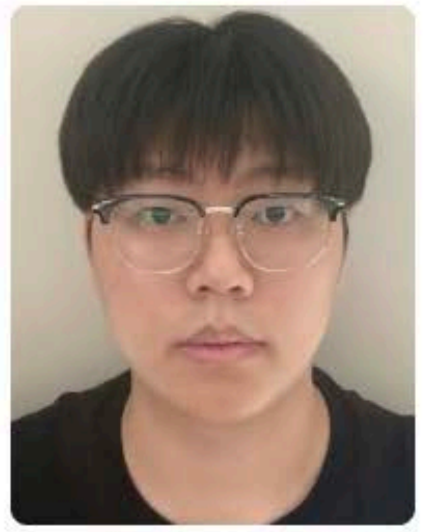
Research Intern

Gengchen Tian

Research Intern

Zehai Liu

Research Intern



Yunhui Song

Research Intern

Haiyang Xu

Research Intern

Junzhe Jin

Research Intern

Join our Team!!

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10 ECTS semester projects

Ongoing Projects:

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ilver ink-
ng

Oral User Interfaces for XR and Health

Embedding Digital Capabilities in Physical Objects

Michael Wessely
michael.wessely@cs.au.dk

Turing Venner
05/08/25

AARHUS UNIVERSITY

Step 1
Generating 3D Model

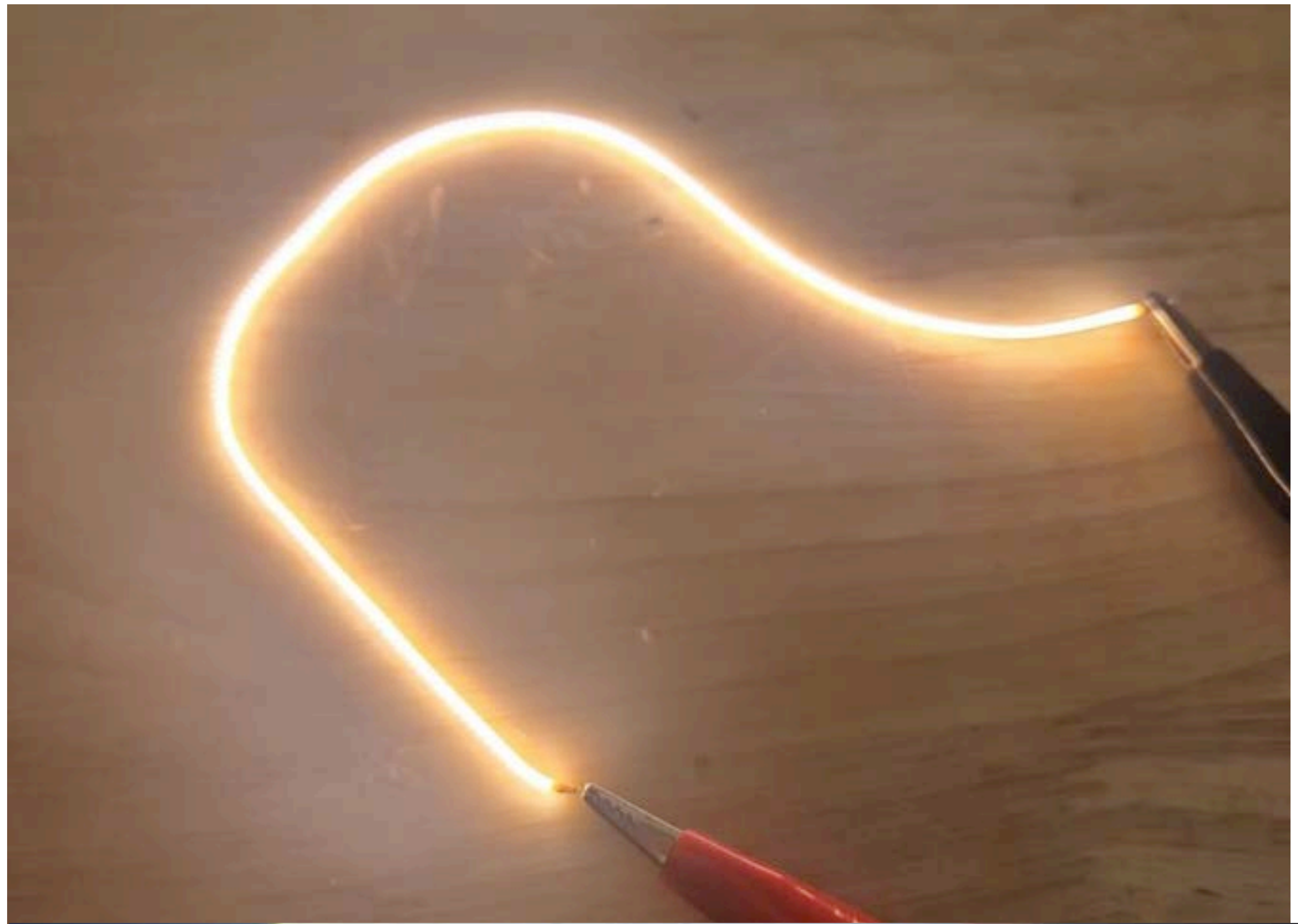
Step 2
Model Processing

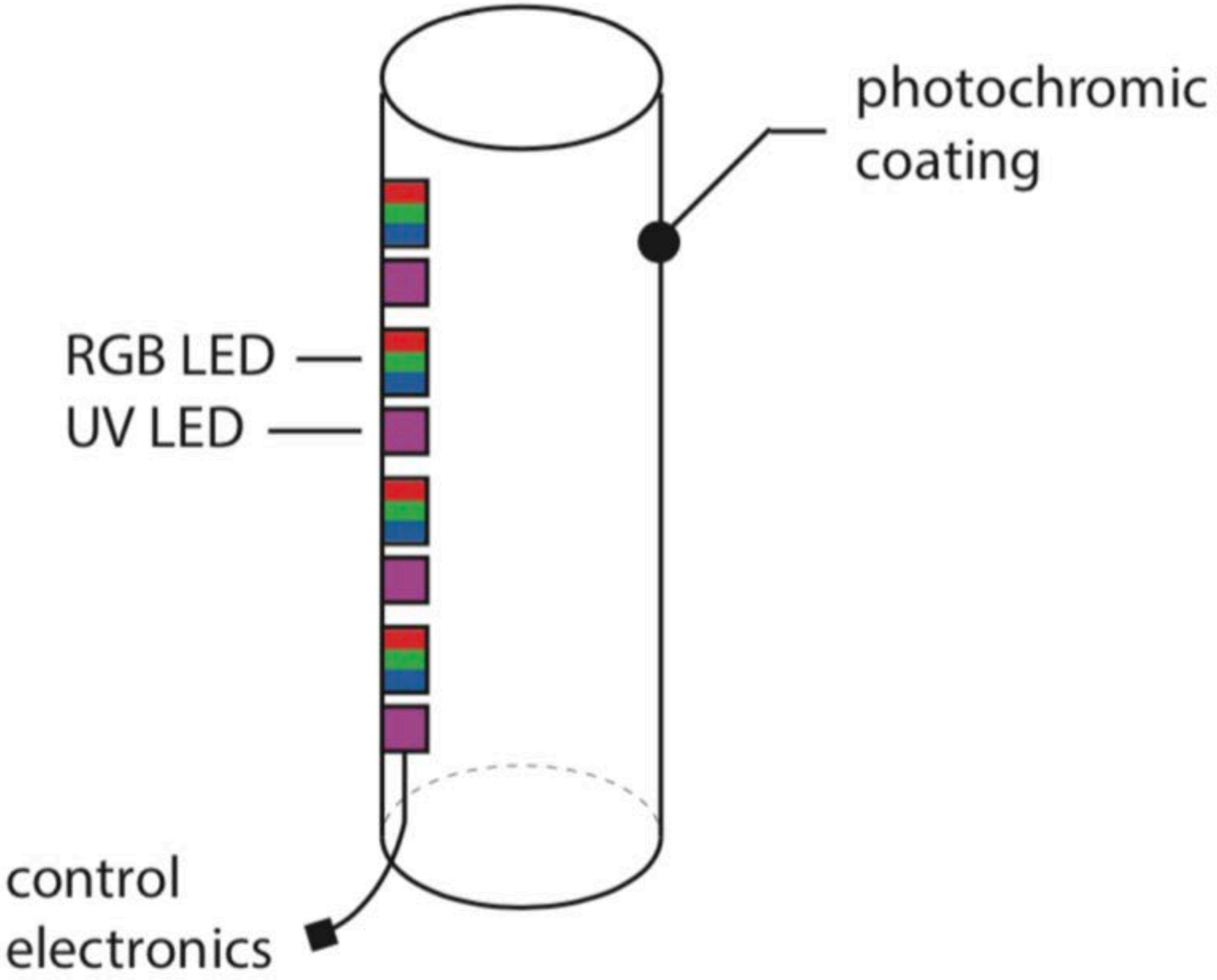
Step 3
Printing the Brace

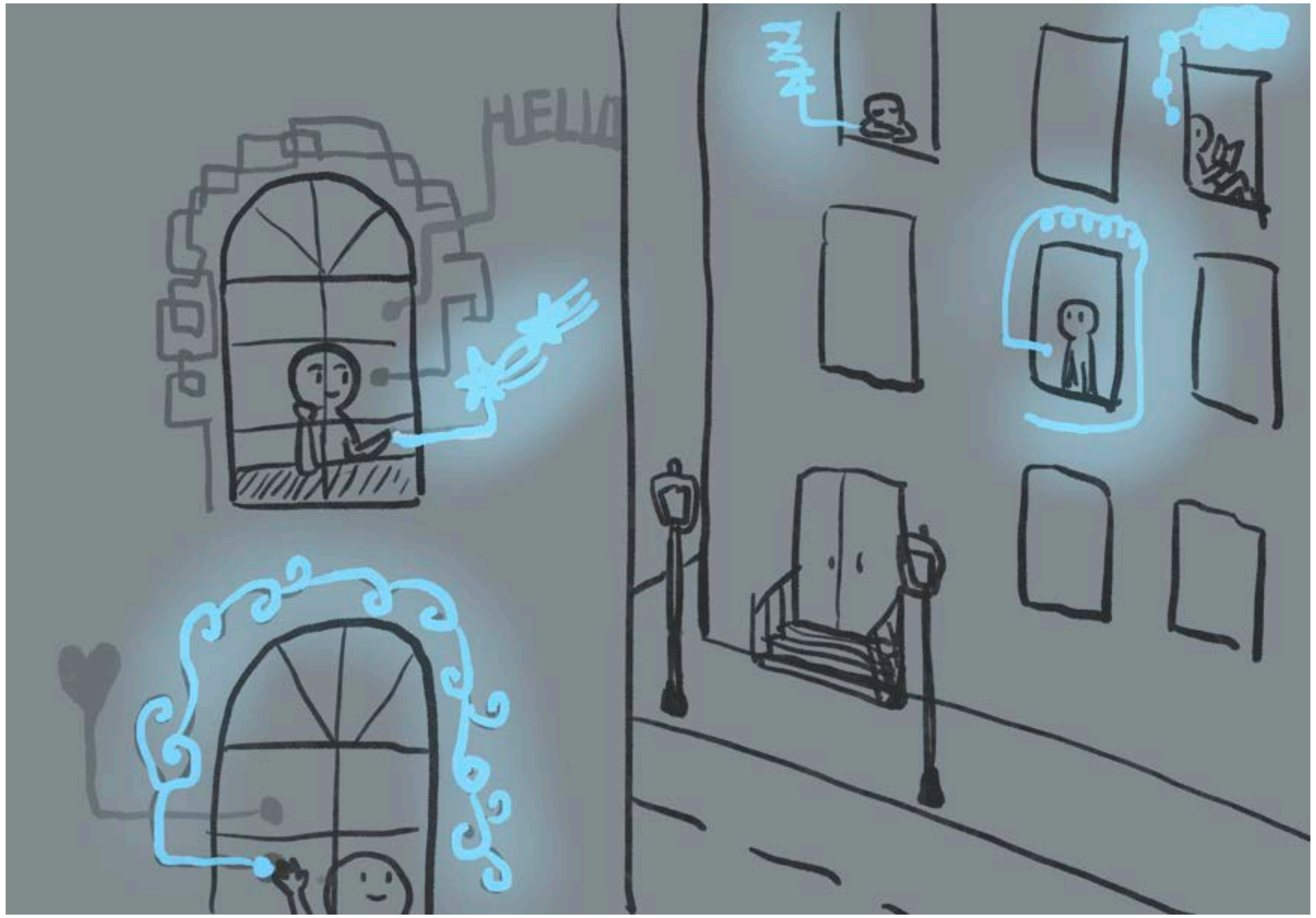
Step 4
Fabricating the Flexible PCB

Step 5
Assembling

Fibre



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