Pushables: A DIY Approach for Fabricating Customizable and Self-Contained Tactile Membrane Dome Switches

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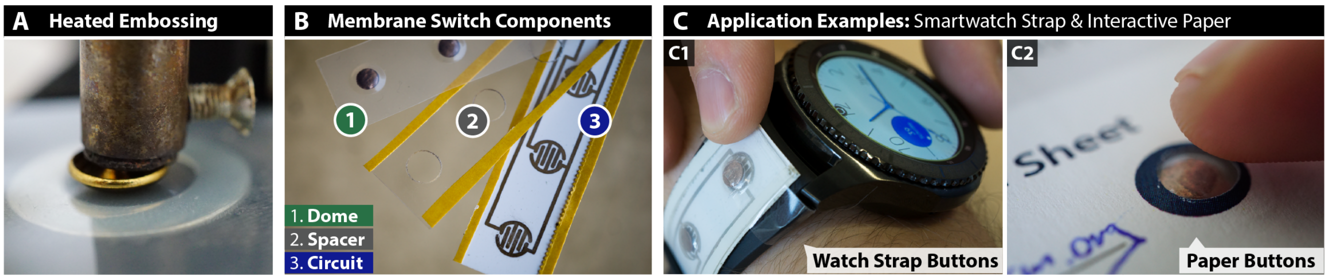

Figure 1. Pushables use heated embossing (A) to fabricate three-layered (B1-B3) custom-defined dome-shaped membrane switches for novel interactive prototypes, such as watch strap (C1) or paper (C2) buttons.

ABSTRACT

Momentary switches are important building blocks to prototype novel physical user interfaces and enable tactile, explicit and eyes-free interactions. Unfortunately, typical representatives, such as push-buttons or pre-manufactured membrane switches, often do not fulfill individual design requirements and lack customization options for rapid prototyping. With this work, we present Pushables, a DIY fabrication approach for producing thin, bendable and highly customizable membrane dome switches. Therefore, we contribute a three-stage fabrication pipeline that describes the production and assembly on the basis of prototyping methods with different skill levels making our approach suitable for technology-enthusiastic makers, researchers, fab labs and others who require custom membrane switches in small quantities. To demonstrate the wide applicability of Pushables, we present application examples from ubiquitous, mobile and wearable computing.

CCS Concepts

•**Human-centered computing** → *Interaction devices; Keyboards; Mobile devices;* •**Hardware** → *PCB design and layout; Haptic devices;*

Author Keywords

paper button, tactile, printed electronics, interactive paper, haptic, membrane switch, dome switch.

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INTRODUCTION AND BACKGROUND

While innovative fabrication and manufacturing technologies have already been in use in industry for a long time, expiring patents, emerging materials, and simplified physical computing toolkits open up new possibilities for technology-enthusiastic makers and researchers. Printed electronics, for instance, allow the rapid prototyping of ultra-thin and flexible circuit boards [8], electroluminescence (EL) displays [12, 7], paper actuators [17], vibro-tactile feedback [2], bend- [16], touch- and proximity-sensors on a variety of materials [5, 4]. Increasingly sophisticated designs and multi-functional surfaces thus become possible. However, they are often still constrained by several conventional off-the-shelf components, such as rigid microcontroller or tactile controls, that do not fit to individual design goals. While the development of complex flexible electronic parts is moving forward at a rapid pace driven by significant industrial investments, passive flexible membrane components, such as tactile membrane switches, are already commercially available today. Unfortunately, they are pre-manufactured and lack customization options. To address this issue, we introduce Pushables as a rapid prototyping approach for creating custom-made tactile membrane switches in small quantities.

While prior research, such as PaperButtons [13] or CircuitStickers [6], enhance surfaces with tactile widgets by augmenting it with attached electronic off-the-shelf components, we aim to seamlessly integrate custom desgined membrane dome switches on the surface itself. Most related to our work, Ramakers et al. [14] introduce paper-membrane widgets, that create an electronic circuit between a planar base and top layer by separating them with thin air gap using a paper frame spacer. With this work, we want to contribute an easy rapid prototyping approach for thermoformed polyester overlays (see Figure 1A & Figure 2, 1) that create rich sensations, enable

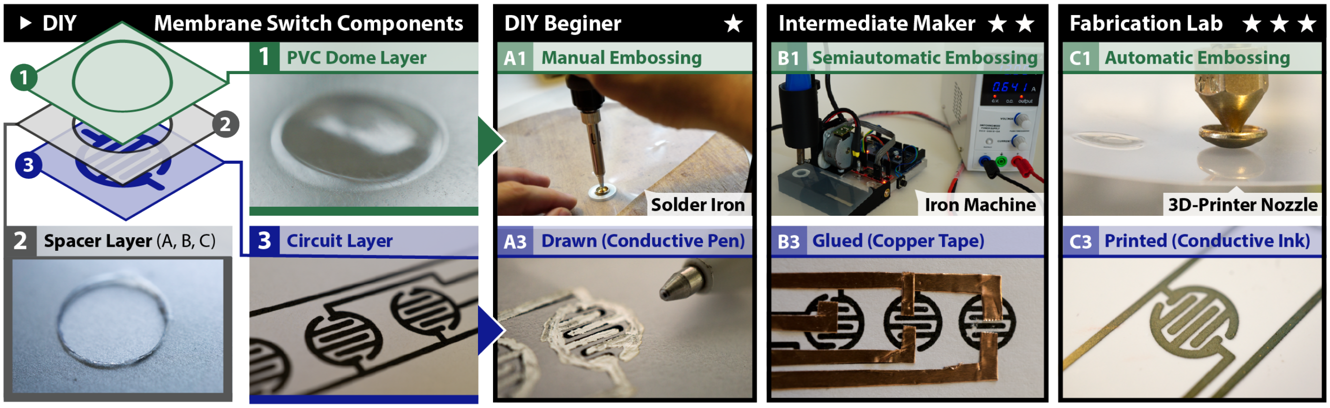

Figure 2. Our Pushables approach provides an easy pipeline to fabricate custom membrane dome switches. Our tactile dome switches consists of a ➊ PVC dome layer, a ➋ spacer layer, and a ➌ circuit layer.

an extended travel retaining the same performance as mechanical push-buttons and provide a set of unique properties among them, ultra-thin, bendable, waterproof and highly customizable attributes.

OUR PUSHABLES DESIGN

Our DIY-fabrication approach for tactile membrane buttons focuses on fast custom designs. Therefore, we contribute a scalable fabrication pipeline[1] (see Figure 2) that is suitable for *DIY Beginer* (⋆), *Intermediate Makers* (⋆⋆) and *Fabrication Labs* (⋆⋆⋆). Basically, our membrane switches consist of three parts: Finger pressure at the switch location deforms the *tactile dome layer* (1) through a *spacer hole* (2) and bridges a switch at the bottom *circuit layer* (3).

➊ **Top Tactile Layer.** To realize membrane buttons with a great tactile feel and nice perceptible counter pressure, we introduce three embossing processes that show how dome-shaped polyester overlays can be DIY fabricated.

***A1.** Manual Embossing:*
The easiest way to built tactile overlays is to manually emboss a dome in a plastic film. We fabricate dome-shaped overlays by attaching upholstery nails to a temperature-controlled solder iron (100°C) which we afterwards press down for 4 seconds into a thin PVC film.

***B1.** Semiautomatic Embossing Machine (Z):*
Since the manual embossing needs exact timings, the approach can be error-prone for composed overlays. To address this issue, we contribute a z-axis embossing machine that handles temperature control and timings. A push-button (or foot switch) triggers an Arduino that starts a linear actuator lowering a hot upholstery nail (cf. manual embossing).

***C1.** Automatic Embossing Machine (X/Y/Z):*
While our semiautomatic embossing approach works like a sewing machine, complex layouts require several manual alignments. In order to fully automate the embossing process along all three axis, we modified the nozzle of a 3D-printer with a upholstery nail. This modification allow us to exactly fabricate complex and more sophisticated dome-shaped overlays.

➋ **Spacer Layer.** The next layer extends the travel of the tactile layer and can be easily produced with hole or offices punchers with standard 0.5 mm thick PVC foils.

➌ **Bottom Circuit Layer.** Finally, we have to realize the circuit switch layer that is bridged by a pressed top layer. This could be done by using conductive pens (A3), glued copper tape (B3) or conductive inkjet-printed [8] traces (C3).

APPLICATION EXAMPLES

To give you a glimpse of the wide applicability of Pushables we discuss three research-oriented applications.

Watch Straps

Watch Straps are typically made of flexible materials that make it hard to attach interactive controls. While current research used covered push-buttons [15] or non-tactile membrane potentiometer [3], Pushables could provide a flexible approach for *back-of-band interactions* (cf. [15]) using tactile membrane buttons (see Figure 1, C1). Furthermore, the top layer of Pushables could also be used to provide tactile feedback for EL buttons [12] that are sensed capacitively.

Interactive Paper

Interactive Paper toolkits (e.g., [14, 10]) enhance paper with digital functionalities and have been combined with multiple input modalities [9] including digital pens [10], capacitive touch [11], bend actions [16], attached components [13, 6] and crafted paper widgets [14]. Integrating our dome-shaped Pushables could extend the repertoire by tactile buttons that provide perceptible, explicit actions (Figure 1, C2).

Medical Prototypes

Medical Prototypes are characterized by strict sterile requirements (cf. [1]) that are often hard to realize in small fab labs. Our Pushable approach provides a fully-functional, waterproof surface and could thereby be useful to fabricate sealed prototypes that can be evaluated in medical studies.

[1]Further fabrication details and part lists are available online on our project website: `https://imld.de/pushables/`.

CONCLUSIONS AND FUTURE WORK

We presented Pushables, a simple fabrication approach for producing membrane dome switches that provide a tactile sensation in a tiny and highly customizable form factor. Therefore, we contributed an easy fabrication and assembly pipeline that demonstrates the DIY production of thermoformed polyester overlays, spacer and a circuit layer for technology-enthusiastic makers, researchers, and fab labs. Finally, we described how our Pushables could enhance physical prototypes and introduced three application examples.

For future work, we plan to build a graphical editor simplifying the G-code generation of our automatic embossing. In addition, we want to emboss more complex forms and patterns to provide further sophisticated tactile widgets. Finally, we aim to investigate new application scenarios, for example, enhancing braille exercises for blind and partially sighted people with Pushables for additional audio information or the development of new thin mobile user interfaces.

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