Polymerized Tape

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Figure 1: Polymerized tape for prototyping input devices. Here tape is used to create functional analog input on (a) the face (b) a soft, elastic object and (c) a rigid object. The elasticity and stickiness of the tape enables robust and effortless deployment, while the functional properties created by polymerization with pyrrole enable high resolution sensing.

ABSTRACT

We present polymerized sports tape as a general purpose prototyping and sensor-design resource. We use it in a somewhat similar manner to how conductive copper tape is often used for fast production of lo-fi electrical prototypes. However, copper tape has a number of drawbacks if one is prototyping with soft materials, textiles, or even directly on the human body. Because it is not elastic, it does not adhere well to such materials. Sports tape, however, has the desired elastic qualities, and additionally is designed to adhere not only to arbitrary objects, but also to human skin. We polymerize sports tape to make it conductive. The resulting conductive tape has a series of electrical properties which make it an exciting sensor-material. It is piezo-resistive. This means its resistance changes with applied forces. It can also be used to create a voltage gradient, which enables simple and precise position sensing. This unique combination of mechanical and electrical properties makes it an exciting and unique prototyping resource.

ACM Reference Format:
Narjes Pourjafarian and Paul Strohmeier. 2021. Polymerized Tape. In *Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '21), February 14–17, 2021, Salzburg, Austria.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3430524.3444706

TEI '21, February 14–17, 2021, Salzburg, Austria

ACM ISBN 978-1-4503-8213-7/21/02.
https://doi.org/10.1145/3430524.3444706

1 MOTIVATION

Embedding interactivity in the physical world requires arranging the world in such a way that we can measure and react to human actions. For example, conductive filament is just another material, until – by correctly arranging it – it magically turns into bend sensors, touch sensors, pressure sensors etc [3]. Ensuring the prototype is not merely functional but also usable, requires the ability to quickly deploy and modify designs [6]. This has led us to explore sensor designs based on various technologies, including capacitive touch [9], resistive sensing [11] and infrared detection [10]. Similarly we have explored methods of simple and fast deployment, from regular printing [9], to 3D printing [3], computer-supported design of free-hand inked circuits [under review at CHI] to simply pinning sensors to clothing [11]. Compared to all these methods, the versatility and simultaneous simplicity of polymerized kinesiology tape is remarkable. We would like to offer a sample of polymerized kinesiology tape to include in the swatch-book. Why polymerized kinesiology tape? Because even though (or maybe because) we have been working with sensor-designs and prototyping tools for some time, the versatility of this hybrid material feels like magic to us.

2 POLYMERIZATION

Based on a process used for manufacturing skin-compatible batteries [1], Honnet et al. presented PolySense, a process for functionalizing arbitrary porous materials and most notably textiles [8]. The functionalization process is based on polymerization of pyrrole. Through in-situ polymerization the target material is coated with a conductive polymer layer. Unlike traditional conductive paint (e.g.: https://www.bareconductive.com/) this process coats the target material on a molecular level. In a fabric, each individual fibre is wrapped in polymer chains (see also Fig. 3). The resulting material turns conductive, typically within the kOhm range. Honnet et al. used this method to create motion-capturing gloves,

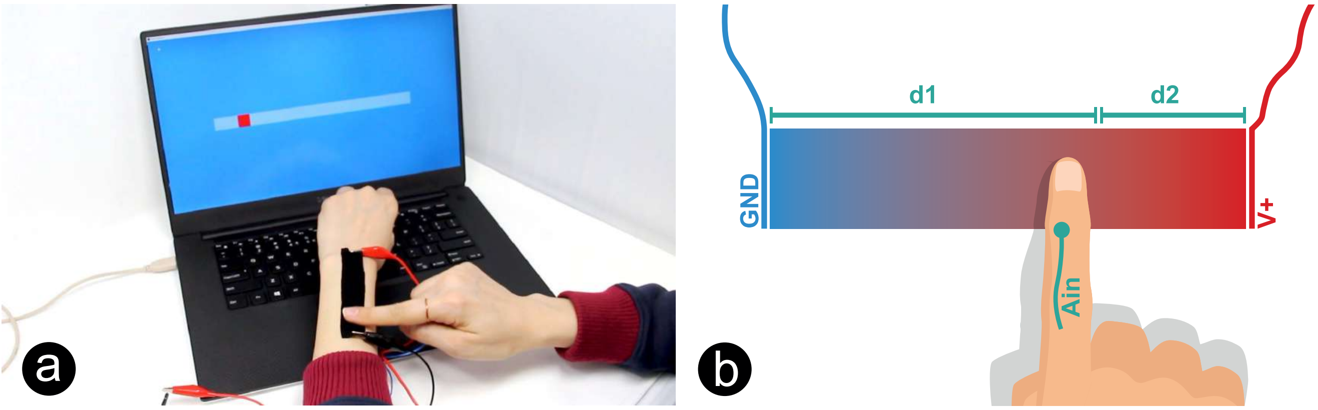

Figure 2: (a) On-Body linear position sensing and (b) the corresponding schematic. Note that the finger used for touching is instrumented to connect to an analog input where the voltage is measured.

computer-controlling leggings, and interactive zippers [8]. Polymerization also inspired various artistic installations, including an interactive dress featuring conductive feathers by Briot [2]. We share polymerization instructions for reproducing our swatch in Table 1.

Figure 3: (a) Fabric samples for testing polymerization, (b) the same samples after polymerization and (c) chemicals used for polymerization (iron(iii) chloride hexahydrate in front, pyrrole in back)

Table 1: How to Polymerize Fabric:

(1) *Choose amount of Water* – The fabric should swim in the water without lumping together, so that monomer and oxidizing agent can reach it everywhere. As a rule of thumb, by weight the ratio of water to fabric should be about 5:1, by volume no more than 4:3.

(2) *Dilute the Monomer* – Add pyrrole to water, creating a water to pyrrole solution with a volume ratio of ~1000:0025. In other words, for each liter of water, add 25ml of pyrrole. Once the monomer is added, stir the solution, until they are well mixed.

(3) *Add Fabric* – Once the fabric is added, stir gently for 10 to 15 minutes. or until satisfied that the fabric has thoroughly soaked up the monomer mixture.

(4) *Add oxidizing agent* – Add Iron Chloride. The mass ratio of Water to Iron Chloride should be 100:001 (i.e., 10g for every liter of water). The iron chloride can either be directly added to the monomer mixture, or the powder can first be diluted with a small amount of water, to improve dispersion.

(5) *Wait for polymerization to complete* – Continuously stir, so that all monomer is brought into contact with fresh Iron Chloride, allowing it to polymerize. Once polymerization progresses, the fabric starts turning black. After about 30 minutes, when all fabric is evenly black, polymerization is complete.

(6) *Remove, Rinse and Dry* – Once polymerization is complete, remove the fabric and wash it thoroughly in cold water. It can then be simply hung up to dry, or ironed, to speed up the drying.

3 SKETCHING

Our research group has a history of exploring epidermal interactive devices [13, 14]. Naturally to us, one of the first things we were interested in trying was creating an epidermal device based on polymerization. Similarly, we have an interest in sketching and rapid prototyping. By sketching we mean any form of low fidelity prototyping which supports exploration of a design space before committing to a single idea or concept [6]. Sketching is of particular importance for the design of epidermal devices, as the device bonds with the user's skin, invading the most personal and sensitive of spaces. This means that the challenges of designing on-skin interactions are not only of technical nature, but are also social and experiential. Consequently, early prototyping and rapid exploration and iteration are especially valuable. In this context, the use of sketching tools – including but also beyond traditional pen and paper – is important [7].

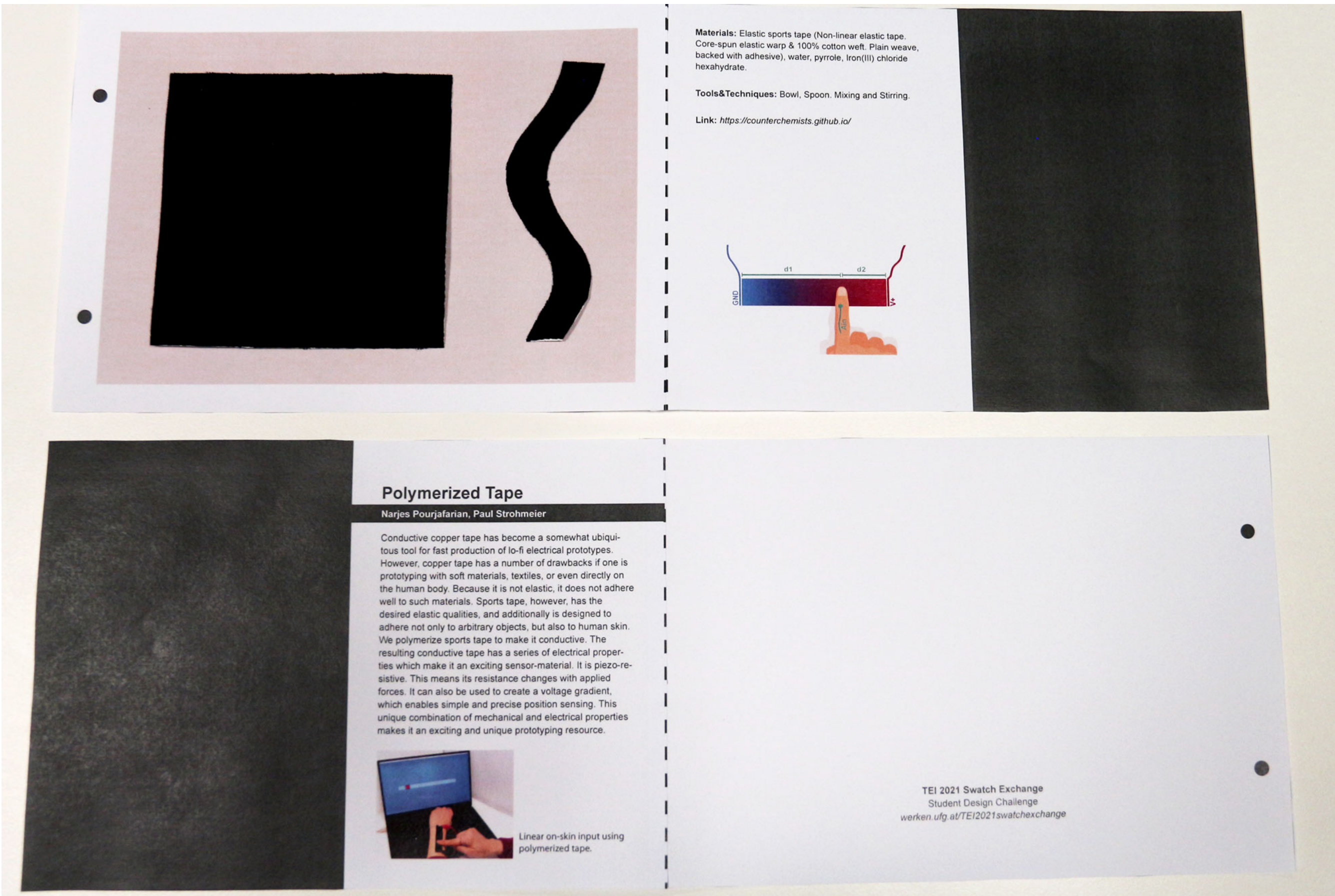

Figure 4: Preview of our page of the swatch-book

4 TAPE

While sketching materials for working on paper, in fabric, or with sculpting materials are common, there are less approaches for sketching on the body. Gannon et al. presented methods for designing non-functional objects on the body [4, 5], but we were searching for something simpler which might also support interactive objects. This is where kinesiology tape comes in: It has a series of properties which make it an ideal candidate for sketching on the body. It comes with a biocompatible adhesive. Its elasticity is designed to match that of the skin. It can be easily cut to shape. It can be applied, removed, modified, and re-applied. While the tape itself is not electrically functional, this could be addressed by polymerizing it.

The samples we wish to contribute to the swatch book were first presented in a paper on sketching interactive devices on the body[12]. We demonstrated that polymerized tape could be used to transfer electrical signals, and to measure pressure, bend, touch, linear touch-position, and 2D gestures on the body.

While we originally conceived of polymerized tape as an on-body prototyping tool, it need not be used that way. Polymerized tape bonds well with fabric as well as a broad range of rigid and flexible materials. Due to its fascinating electrical sensing abilities, and its convenient mechanical properties, it has become one of the most useful and versatile tools in our rapid-prototyping arsenal.

ACKNOWLEDGMENTS

We wish to acknowledge the many people who were instrumental in making this submission happen. First of all thanks to all our colleagues at the UdS, especially Bruno Fruchard, Marc Teyssier and Jürgen Steimle. We also thank Hannah Perner-Wilson of Kobakant for her major input in how we now work with polymerization. We thank all the creative minds at Datapaulette, especially Audrey Briot and Martin De Bie for exploring this space with us. Finally we thank Ana Baptista for providing her expertise on materials and, last but not least, a big THANK YOU to Cedric Honnet for making all of this come together.

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