Material-centric personal fabrication to enable prototyping of electronics and interactive devices on-demand.

OLLIE HANTON, University of Bath

Additive manufacturing has shown phenomenal growth in recent years, enabling democratised decentralised production of free-form artefacts and prototypes. However, these are typically inactive. By adhering to the same core principles, we propose that the exploration of automated deposition of active materials has the same potential for growth within electronics fabrication. This research holds the potential to unlock new forms of electronic device and the possibility for use by non-specialists in a manner akin to domestic 3D printing. In our published work we carry out 1) explorations of automated deposition methods, 2) active material investigations and 3) research into integration of design within fabrication processes. The work that we present here explores interactive devices, as a set of implementations that benefit most from the ability for irregular form and insitu customisability related to display fabrication. However, in this position paper we argue that these three key research angles provide the potential for greater democratisation in an even broader range of electronics prototyping methods, beyond just interactive devices, such as laying of conductive traces and augmentation of passive objects with sensors.

CCS Concepts: • **Human-centered computing**;

Additional Key Words and Phrases: Electronics Fabrication, Personal Fabrication, Active Materials, 3D Printing

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1 INTRODUCTION

In our work [1, 2, 9], we provide new methods and material explorations for the personal fabrication of displays. We explore the development of methods and research that lead towards new forms of interactive devices, with the aims of facilitating a new range of forms for devices through active display materials and structures. In this way, we look at developing methods for high fidelity prototypes. However, our work acts as a stepping stone to going beyond prototyping into the potential for domestic fabrication of end-products.

We advocate that by exploring active materials in depth and developing safe-to-handle conductive and active display materials, we are in a position to leverage one of the core tenets of personal fabrication: the additive manufacture of structures using mutable materials rather than components. This research opportunity opens the potential for domestic or semi-domestic automation of fabrication of circuits, sensors and display elements. Through this automation, non- or semi-specialist fabrication can be facilitated in a similar manner to 3D printing, and a new array of circuit form-factors can be realised.

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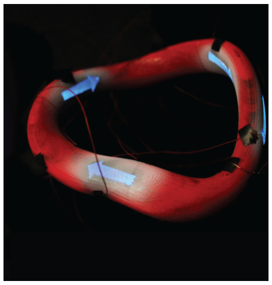

Fig. 1. A demonstration of the ProtoSpray fabrication process: An irregularly shaped set of displays consisting of 7 segments as arrows on a 3D printed mobius strip.

We present our ideas relating to electronics fabrication as a whole, but focussed on the input and output nature of electronically active materials. These cover capacitive touch through conductive paint, as well as output through electroluminescent and E ink materials. In the context of this workshop, we primarily align our goals with 2.4 "New materials and new form-factors for electronics". We structure this paper to cover 1) where our existing work aligns best with extensions of the vision of "Beyond Prototyping Boards" and 2) a cross-section of the alignment of visions of electronics fabrication and those of material centric display fabrication.

2 HOW OUR WORK ON PERSONAL DISPLAY FABRICATION FITS "BEYOND PROTOTYPING BOARDS"'S VISION

2.1 Automated deposition

Within our project "ProtoSpray" [2], we innovate and evaluate the partially automated process of 3D printing conductive channels and spraying active materials to produce free-form interactive objects using existing domestic fabrication tools (am FDM 3D printer and airbrush). An example of a fabricated device is shown in Figure 1. This process builds on work exploring automated deposition of conductive filament [8].

We see this process as an initial foray into the development of bespoke systems and machines to tackle the problems associated with domestic electronics fabrication. Tools such as the Optomec 3D printer [7] show the feasibility of lab/factory based fabrication of custom circuitry, however we identify factors such as health and safety, usability and cost when scaling to a domestic or hackspace-like setting. This in turn limits the potential of decentralised democratised fabrication of electronics giving rise to the need for bespoke safe affordable tools.

2.2 Material democratisation and development of User-friendly materials

Within two of our presented projects: FabricatINK and ProtoSpray, we explore different active materials and their properties. The motivation for the FabricatINK project was to explore a cheaper, less dangerous, optimal display material rather than toluene-suspended electroluminescent particles [5]. In this project we looked at democratising E ink as a material. We contributed a hacking process (see Figure 2) for E readers through which we upcycled the E ink into a fabricatable material. This work acts as a stepping stone towards liberating this material for use within display fabrication.

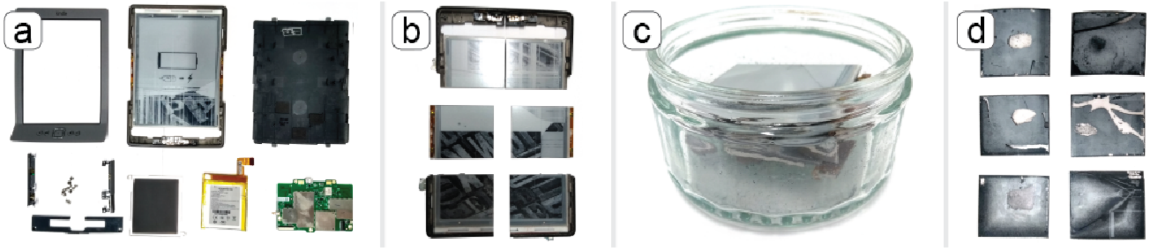

Fig. 2. The extraction process developed within FabricatINK in order to gain access to E ink for exploration and adoption as a material for use within personal fabrication.

We propose further such work, exploring a broader range of existing display materials for use within personal fabrication settings, as well as development of novel structures where possible. This imperative also applies to ProtoSpray, where the novel pairing of conductive PLA and electroluminescent materials allows for direct integration of display fabrication into 3D printing. In this context, we layout goals such as safety, reliability and readily available knowledge from a materials perspective.

2.3 Integrated design building on HCI's interaction design.

Lastly, in our work we make initial investigations into integrating design within the context of Display Fabrication. Sprayable User Interfaces [9], explores using a plugin to existing CAD software to enable easier design of stencils and overlays to support spraying of active materials. We propose extending this work, and are currently in the process of exploring this space.

3 HOW "BEYOND PROTOTYPING BOARDS"'S VISION SUPPORTS DRIVING OUR FUTURE ACTIVE MATERIAL-CENTRIC RESEARCH

3.1 Developing novel design structures for fabricated electronics

One of the adjunct impacts of 3D printing growth is the adoption and acceleration of hobbyist CAD use in order to enable personal fabrication. If our stipulation, that electronics fabrication can follow the same route as inactive personal fabrication, is correct then the development of suitable and accessible workflows and design tools will be crucial. We propose that rather than developing these processes ad hoc, in response to the needs of the field, we integrate core areas of HCI interaction design research into tools in parallel with developing deposition methods and materials.

3.2 Developing seamless bridging between material and component based electronics

In our work we have identified the non-trivial problem of integrating a material-centric input/output approach with a component-based driver. Our inability to accurately (and definitely not domestically) print transistors and computational circuitry, means we rely on microcontrollers for material-centric circuits. In our work we have developed work-arounds to attach materials temporarily to control circuits, but we propose research into bridging this gap to improve usability for makers and increase adoption of material-centric fabrication methods.

3.3 Developing compact appropriate drivers and control

Although there are some drivers and appropriate supporting control architecture, along side appropriate design tools, in order for democratisation to truly be a goal of material-centric electronics fabrication, we propose the need for significant development of accessible and usable drivers. We suggest the frameworks of [3, 6] as a starting point with non-academic projects such as Ben Krasnow's work [4] demonstrating feasibility.

4 BIOGRAPHY

Ollie is a lecturer (assistant professor) at the University of Bath, exploring the personal fabrication of free-form interactive devices by non-specialists. His work focusses on creating displays using spraying, through active materials such as electroluminescent paint. His work is positioned between the disciplines of HCI and both material science and engineering.

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