Crafting Interactive Circuits on Glazed Ceramic Ware

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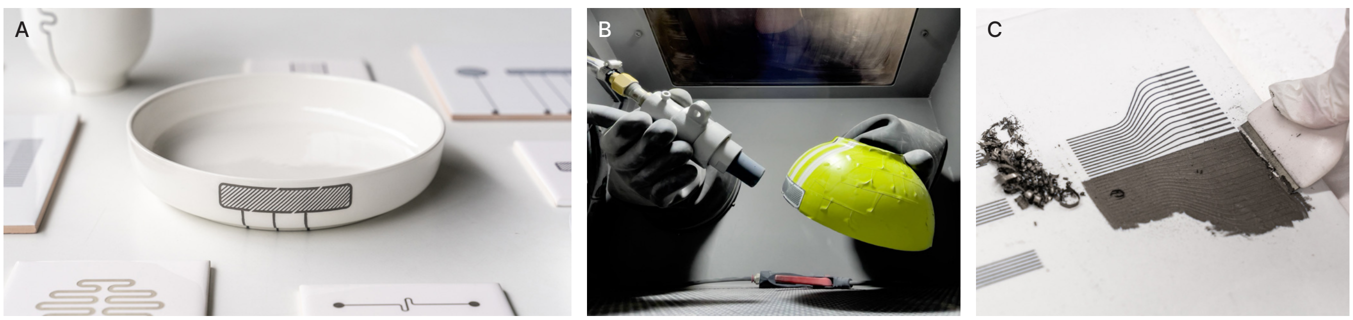

Figure 1: A: Glazed ceramic collection instrumented with interactive circuits based on our approach. B: *Resist-blasting* a glazed ceramic object. C: Scraping excess conductive ink to reveal the underlying circuit.

ABSTRACT

Glazed ceramic is a versatile material that we use every day. In this paper, we present a new approach that instruments existing glazed ceramic ware with interactive electronic circuits. We informed this work by collaborating with a ceramics designer and connected his craft practice to our experience in physical computing. From this partnership, we developed a systematic approach that begins with the subtractive fabrication of traces on glazed ceramic surfaces via the resist-blasting technique, followed by applying conductive ink into the inlaid traces. We capture and detail this approach through an annotated flowchart for others to refer to, as well as externalize the material insights we uncovered through ceramic and circuit swatches. We then demonstrate a range of interactive home applications built with this approach. Finally, we reflect on the process we took and discuss the importance of collaborating with craftspeople for material-driven research within HCI.

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CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**.

KEYWORDS

Craft, Ceramics, Interactive Circuits

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1 INTRODUCTION

Glazed ceramic is a versatile material and people use it everyday. Humans have long harnessed this material and its many qualities to make practical and decorative objects—from dining and kitchen ware, to home and architectural fixtures. We are attracted to the modest and democratic presence of glazed ceramic ware. And, as HCI researchers, we believe that these everyday artifacts, and the craft practices around them, offer fertile ground to broaden the diversity and expression of ubiquitous computing systems.

In this research, we explored glazed ceramic ware as a platform for interactive interfaces. Specifically, we investigated instrumenting glazed ceramic ware with electronic circuits with the processes and tools found in the ceramics workshop. Through our exploration, we developed a systematic approach to incorporate circuits into ceramic artifacts. The approach we developed is built on the practice of Hans Tan, a designer who works with sandblasting to create intricate patterns on porcelain ware (Figure 2). To create these pieces, Hans Tan developed the *resist-blasting* technique which involves selectively sandblasting the glazed porcelain surface (Figure 2C). As colleagues and collaborators, we had the opportunity to physically handle these pieces, as well as watch him conduct his craft in person. The physical details of these crafted pieces stood out to us as researchers with experience in building interactive circuits. The rough "valleys" that resist-blasting created on the surface of glazed porcelain seemed like an ideal substrate for applying conductive inks—and we hypothesized that this process can be adapted to apply circuits onto glazed ceramic objects.

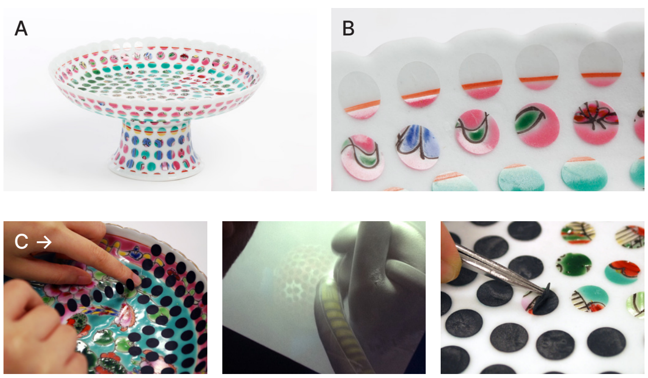

Figure 2: A: A piece from Hans Tan's design collection. B: Close up of resist-blasted surface details. C: Process of masking, sandblasting, and removing mask from glazed porcelain object.

With this as a starting point, we set out to explore resist-blasting and glazed ceramic, directing this craft toward incorporating interactive circuits into glazed ceramic ware. This involved sensitizing ourselves to resist-blasting, the different types of glazed ceramics, and their combination with new materials such as conductive inks. We also worked closely with Hans Tan (who is a co-author in this work) through practical workshops and discussions to systematically characterize the tacit craft knowledge that he has gained over many years of practice—externalizing the affordances and constraints of the material and process for other designers and researchers. We then demonstrate the approach we developed by building a range of applications for different home contexts, including dining vessels and wall tiles that sense and support everyday activities and interactions.

1.1 Contributions

In this paper, we report on the process of our material-driven inquiry into glazed ceramics and interactive circuits, detail the approach we developed, as well as showcase the interactive applications we built with it. We contribute to the research and discourse surrounding HCI, craft and design, and tangible computing in the following ways:

(1) The main contribution of this work is the new approach we developed to instrument existing glazed ceramic ware with interactive circuits through resist-blasting, leveraging tools and processes that are primarily used in the ceramics workshop. This approach enables designers to create circuits over the complex, three dimensional, surfaces of existing ceramic objects. It also offers a high degree of control over the circuit's visual appearance.
(2) We showcase a range of circuits capable of different functions (such as sensing and heating) built with the approach. We also developed a series of applications with these circuits to demonstrate how our proposed approach might be used to craft interactive ceramic ware that participate in everyday home activities.
(3) We examine the process we took and discuss what we learnt from collaborating with a ceramic crafter and his individual craft practice. With this, we provide further evidence for the growing body of work that argues for the participation of craftspeople in influencing and informing material-driven design research in HCI.

2 BACKGROUND & RELATED WORK

Our work is informed by many theoretical concepts and related work from research in HCI and interaction design. In this section, we trace and discuss the important pieces that underpin our material-driven inquiry into glazed ceramic as a platform for electronic circuits and tangible interactions.

2.1 From Ubiquitous Computing to Interactive Materials

Ubiquitous computing proposes a vision of the world where computational technology "disappears and weaves itself into the fabric of everyday life" [51]. This vision pushes HCI researchers and designers to consider how interactive systems can become holistically integrated into our day-to-day activities and physical spaces. This, in turn, emphasizes the tangible aspects of an interactive system and how it is embedded and embodied in the real world. Some recent examples that researchers have demonstrated include interactive systems integrated into decorative home ware [28], domestic devices [22], tableware [24, 27], and personal accessories [33].

In developing these tangible interfaces and interactions, HCI researchers highlight the importance of *materiality* and *material-driven design* [19, 52]. Gross et al. [13] captures three main strands of materiality research within HCI: *Physical materiality* considers the affordances of physical materials for information and interaction [15, 30, 48]. *Computational materiality* considers computation and its properties as a material that are composed with other physical materials to give *composites* [49] or *textures* [40] that express "relations between physical and digital". *Craft materiality* considers interaction design within our rich human tradition in making and expressing ourselves through physical artifacts. This includes "creating knowledge through deep, embodied engagement" [12] by connecting the traditions, tools, and values surrounding crafts with (relatively) newer digital technologies.

Table 1: Related work in the area of making interactive electronic circuits through textiles, body decoration, and paper craft.

Category	HCI Research Examples	Practices/Processes	Construction materials (*computational) *excluding microcontroller and commercial electronic components*
Textiles	Perner-Wilson et al.[1] [35] Devendorf et al.[2] [11] Posch & Kurbak[3] [38] Wu & Devendorf[4] [53] Honnet et al.[5] [14]	Sewing[1,3], Knitting[1], Crocheting[1,2,3], Felting[1], Weaving[2,4], Polymerization[5], (Tie, Batik) Dyeing[5]	Fabric[1,2,3,5], Fiber[1], Yarn[1,2,3,4,5], *Conductive Fabric[1], *Conductive Yarn[1,2,3,4], *Metal Beads[1], *Enameled copper wire[3], *Thermochromic paint[2], *Magnetic beads[3], *Conductive polymerization chemicals[5]
Body decoration	Kao et al.[1] [18] Sun et al.[2] [44]	CNC Cutting [1], Temporary tattooing[1], Gold-leafing[1], Weaving[2]	Temporary tattoo paper[1], Skin-safe adhesive[1,2], *Metal leaf[1], *Conductive yarn[2], *Enameled copper wire[2], *Thermochromic yarn[2], *Shape memory alloy[2]
Paper	Qi & Buechley[1] [39] Shorter et al.[2] [42] Zheng et al.[3] [55] Torres et al.[4] [46]	Paper cutting/folding[1,3], Drawing/painting[1,4], Printing[2,4], Silkscreening[2], Laser cutting[3]	Paper[1,2,3,4], Metal clips[1,2], Ink/paint[1,2,4], Kapton tape[4], *Copper tape[1,2], *Conductive ink[2,4], *Conductive epoxy[2], *Carbon-coated paper[3], *Thermochromic pigment[4]

The work we present in the paper is driven by our exploration into the craft practices surrounding glazed ceramics—in particular, the process of resist-blasting. While coming to terms with the new craft at hand and the practice of a particular craftsperson, we brought in our experience as designers and builders of interactive systems—entangling the materiality of the craft we were investigating with the physical and computational materiality of tangible interfaces and interactive electronics. To support our investigations in such a multifaceted space, we drew inspiration from related work in HCI that explored harnessing traditional craft for interactive circuits.

2.2 Crafting Interactive Circuits

HCI researchers have explored and integrated traditional crafts into a wide range of approaches for producing interactive electronic artifacts. This body of work is characterized by "combining, aligning, and integrating analog and digital crafting techniques and processes" [12]. Table 1 presents a snapshot of the related work in this area, organized into three categories of traditional craft—textiles, body decoration, and paper.

Barati & Karana [3] discussed that the development of novel and useful physical products and systems requires designers' to actively participate in "discovering the novel potentials of materials rather than merely translating the given materials information to product applications." One striking feature of the related work is this discovery of *new electronic functionality* within both traditional and new materials when translating traditional craft practices for the production of interactive systems. For instance, researchers leveraged decorative metal beads [35] and gold leaf [18] as conductive electrodes, or carbon-coated paper [55] and chemical dyes [14] for piezoresistive sensing.

Related work on crafting interactive circuits not only expand the materials that participate in the design of interactive systems—they also broaden the cultural practices and communities that engage with electronics and computational technology [6]. This stood out to us when we observed the independence and specificity of the different approaches presented in Table 1. Each work kept the materials, tools, and processes of crafting interactive circuits largely within existing practices of the specific craft at hand (for instance weaving [11] or papercrafting [39]). New processes, if required, were introduced in a manner that is easily adopted by the craft in question—for instance, leveraging *batik* dyeing along with polymerization to instrument fabrics with piezoresistive capabilities [14]. It is also interesting to note that digital fabrication processes were incorporated into some work to maintain the "self-sufficiency" [12] of crafting approach, such as supporting crafters to fabricate intricate circuit templates through machine cutting [18, 55] or inkjet printing [42, 46].

While we acknowledge that the list in Table 1 is non-exhaustive, we highlight these specific works because they were influential case studies to our approach—namely, because they present work that is fundamentally centered on bringing new materialities already present and rooted in craft traditions to HCI for consideration. In this research, we add a new set of tools, processes, and materials to the diverse range of practices and communities involved in crafting HCI—introducing *crafting interactive circuits on glazed ceramic ware*. We took reference from the previous work and worked closely with a ceramics crafter to keep our approach not only within the practices of the ceramics workshop, but also anchored on the unique craft practice (resist-blasting) of our craft collaborator—while carefully considering the role of new tools and processes that we introduce to the craft. We elaborate on the position we take later in the discussion (section 7) by reflecting on a distinct category of research projects emerging from the discourse on material-driven design that investigates the value of collaborations with craftspeople for HCI.

2.3 Ceramics as a Locus for HCI Research

Ceramics is one of human's oldest making traditions—a craft that endures and is still widely practiced today. It offers a rich context for research into materials, making, and objects. Researchers have explored the medium of ceramics within HCI from various angles: Rosner et al. [41] investigated ceramic practices alongside interactive circuits and digital fabrication. From these experiences, they discussed the tensions and learnings that emerged between "code and clay", such as a renewed attention and appreciation for embodied gestures in interacting with digital technology and code. Desjardins & Tihanyi [9] explored translating ambient sound recordings into machine code for 3D printing ceramic cups. With these artifacts, they probed data physicalizations through the lens of machine affordances, tactility, and everyday use. Nabil & Kirk [28] and Lin et al. [24] used everyday ceramic objects as a platform and developed prototypes that speculated on the form and presentation of interactive systems at home. Moradi et al. [26] examined the material practice of six experts with regard to glazing ceramic objects and offered recommendations on how these practices might inform other material-driven explorations in HCI.

In this research, we attend to ceramics as a ubiquitous physical material and its potential for interactive circuits—contributing to the rich conversation around this material for HCI research. It is relevant to note that within the many practices surrounding ceramic craft, there are a few traditional techniques where conductive material is applied to ceramic objects. These include *kintsugi* (repairing breakage with lacquer and powdered gold), gilding ceramics (surfacing with gold leaf), as well as *cloisonné* (enamel held in place by metal wire). While these techniques are viable avenues for us to explore circuitry on glazed ceramic ware, we chose to focus on exploring resist-blasting; leveraging the opportunity to work closely with an expert of the technique to pursue our observations for applying functional and aesthetic circuits.

3 MATERIAL-DRIVEN EXPLORATIONS

We began our material exploration by familiarizing ourselves with different types of glazed ceramic ware and the resist-blasting process. We then directed our insights on the materials and processes toward creating circuit patterns and applying conductive ink onto glazed ceramic parts.

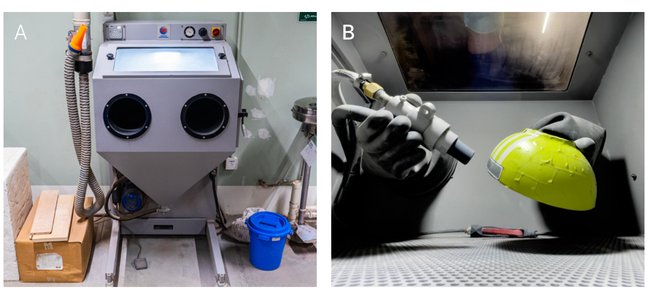

Figure 3: A: *Kompac Blaster* sandblasting machine. B: Machine interior.

3.1 Sandblasting Glazed Ceramics: A Brief Introduction

Glazed ceramic is typically formed from a two-step firing process of clay. First, clay is shaped and bisque fired in the kiln. This first firing results in a bare ceramic object that is subsequently coated with a glaze material and fired for a second time at a higher temperature. The glaze forms a vitrified (glass-like) and waterproof coating on top of the ceramic, resulting in a material with two distinct layers: an inner ceramic layer that is coated with an outer glaze layer (Figure 4A). The final material acquires its many qualities from this process, including being durable, sanitary, and heat resistant. As kiln firing operates at a very high temperature (approximately 1000°C to 1400°C), electronic components and metals can only be added to ceramics *after* firing has completed. This includes adding metals with the traditional techniques described earlier (*kintsugi*, gilding, and *cloisonné*); or adding interactive electronic parts to ceramic objects (e.g. [54]).

Sandblasting is a post-process technique for glazed ceramic objects. It involves directing a high pressure stream (blasting) of abrasive grit (sand) at the artifact. This is capable of removing the glaze layer as well as the base ceramic material. In this work, we specifically used the *Kompac Blaster* sandblasting machine (Figure 3) set at approximately 40 psi, and brown aluminum oxide #220 powder as the abrasive grit (Figure 4B). We documented the effect on sandblasting on different types of glazed ceramic in Figure 4.

3.2 Resist-Blasting Workshop

As a craft practitioner, Hans Tan works with porcelain ware to express themes around Singapore's heritage, local identity, repair, and restoration. Part of his practice is characterized by applying contemporary patterns on traditional porcelain vessels with the resist-blasting technique (Figure 2). Physically, these pieces are characterized by contrasting patterns of the glossy original surface of the vessel with the matte unglazed porcelain underneath.

This contrasting texture stood out to us as tangible interaction designers and we hypothesized that conductive paint will adhere to the rougher unglazed ceramic bisque but not to the glazed surfaces. If so, this will enable us to define functional and visually complex interactive circuits on glazed porcelain ware.

With these ideas in mind, we kicked off the exploration with a resist-blasting workshop facilitated by Hans Tan (Figure 5A). We worked with Hans Tan to prepare the tools and materials for the workshop, including a variety of glazed ceramic ware and tiles for sandblasting. This workshop was conducted at a university maker space. Hans Tan named the technique *resist-blasting* as it is conceptually similar to the resist dyeing process used for selectively adding pigments to textiles. Resist-blasting in contrast, is a subtractive process defined by the following steps:

(1) A 2D pattern is cut on adhesive vinyl film with a computer-controlled plotter.
(2) The patterned film is then transferred onto the porcelain object, which serves as a mask to selectively expose the glazed surface (Figure 5C).
(3) The masked object is manually sandblasted. Sandblasting abrades and removes the unmasked glazed surface of the porcelain object, gradually exposing the unglazed ceramic underneath (Figure 5D).
(4) Finally, the vinyl mask is removed, revealing the transformed ceramic object.

This workshop equipped us (members of the research team without prior experience) with the basics of the resist-blasting technique. However, there were still many gaps between what we experienced in the workshop, and our goal of crafting interactive circuits. For instance, electronic traces are typically long meandering lines that branch across a circuit board to transmit signals and connect components together. Such structures are different from the patterns

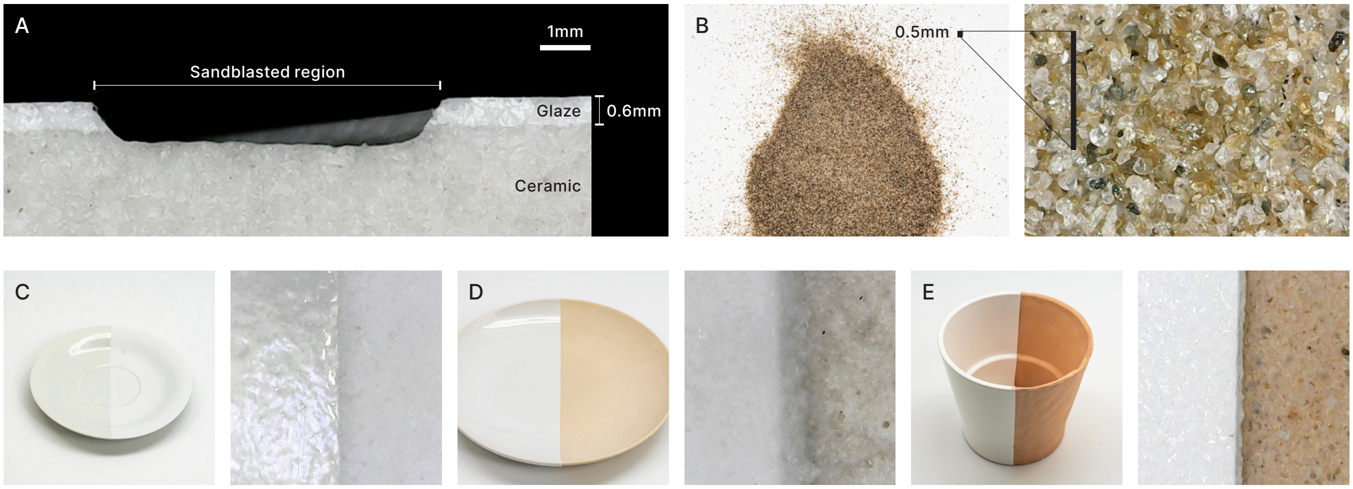

Figure 4: A: Cross section of a glazed ceramic object that was sandblasted under a microscope. B: Brown aluminum oxide #220 abrasive grit, regular photo and under a microscope. C: Half sandblasted porcelain dish, D: half sandblasted stoneware dish, E: half sandblasted earthenware pot.

Figure 5: Scenes from the resist-blasting workshop. A: Hans Tan demonstrating masking and B: resist-blasting. C: A research team member applying a vinyl mask to a porcelain bowl. D: Resist-blasting the porcelain bowl in the sandblasting machine.

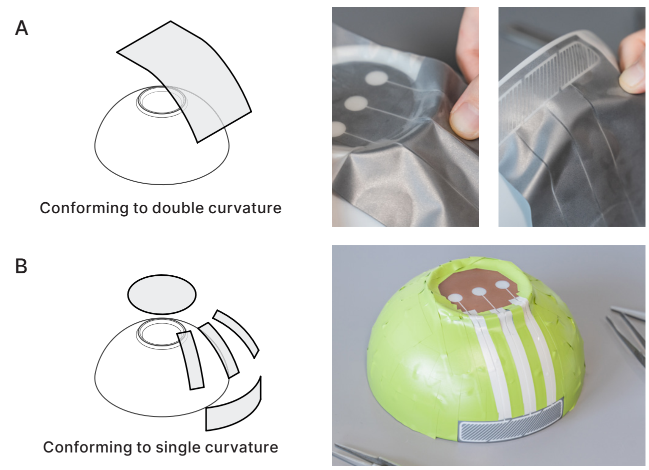

Figure 6: A: Applying a circuit pattern with a large mask onto a doubly curved surface of a bowl. B: Dividing the same circuit pattern into different regions that conform to a single curvature.

that Hans Tan employs in his work—small repeating motifs that cover the surface of the ceramic object. We were also interested in applying interactive circuits to other ceramics types besides porcelain. As such, we branched out and investigated how we might leverage resist-blasting for incorporating interactive circuits and conductive paint into glazed ceramic ware. We describe our explorations in the following sections, including the challenges and insights that emerged.

3.3 Masking Continuous Patterns

We used a *Cricut Maker* machine to cut circuit trace masks on adhesive vinyl film. The main challenge we encountered in this process was transferring the 2D mask onto the 3D surface of a ceramic object. Compared to the small repeating masks used in Hans Tan's work, circuit traces need to be continuous and require larger masks. These larger masks were difficult to transfer onto the doubly curved surfaces of ceramic vessels, as well as across the object's rim (Figure 6A). We took cues for pattern making in shoe and garment design (e.g. [29]), and deconstructed the ceramic object we had to mask into a series of smaller flat patterns that conformed predominantly to a single curvature (Figure 6B). We minimized the breakup of important circuit features when deconstructing a ceramic object into flat patterns. For instance, keeping the entire region of the touch sensor electrodes on a bowl in one piece.

3.4 Sandblasting Circuit Traces

We explored resist-blasting on a broader range of materials beyond porcelain, expanding the resist-blasting technique to stoneware and earthenware objects (Figure 4C,D,E). We also experimented with different types of surface finishings beyond the high temperature glazes typically used for porcelain ware, including low temperature glazes and powder coatings. In these experiments, we attempted

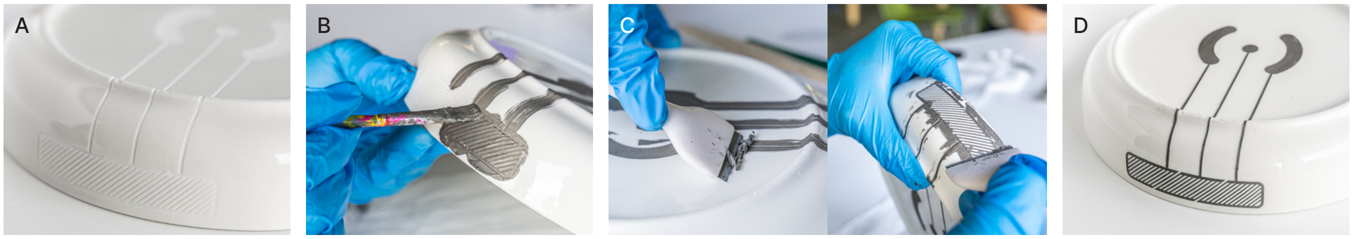

Figure 7: Scraping process. A: Glazed porcelain bowl with resist-blasted traces. B: Painting on the conductive ink with a brush. C: Scraping the excess dried ink off the bowl with a metal flat head scraper. D: The cleaned bowl with inlaid conductive traces.

to remove all the glaze till we reached the underlying ceramic. We assessed the control we had over the sandblasting process by measuring the consistency of the depth of material removed.

As expected, porcelain ware with high-fire vitreous glaze exhibited the most uniform material removal with sandblasting—after all, the resist-blasting technique was developed for this specific material. We posit that sandblasting has a similar effect on porcelain ceramic and the outer glaze due to their similar textures (see microscope view Figure 4C). On the other hand, it was more challenging to uniformly sandblast softer ceramics like earthenware. Material removal is more aggressive and inconsistent at areas with exposed earthenware ceramic (Figure 8).

Overall, it was also easier to achieve consistent material removal for narrow traces than wide traces or large patches (see resist-blasting swatch document, Figure 10 insight 8). In addition, some non-vitrified coatings resisted sandblasting. We suspect that these coatings contain plastic materials that resists sandblasting the same way that the vinyl mask does.

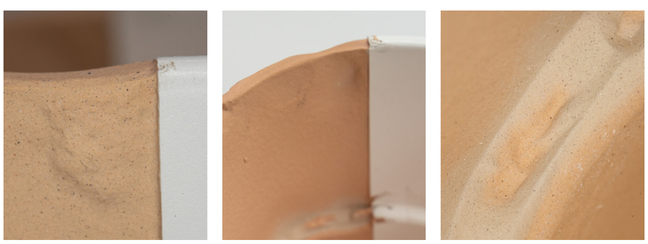

Figure 8: Inconsistent material removal for earthenware.

3.5 Applying Conductive Inks

We experimented with manually painting different types of acrylic-based conductive inks (Table 2) onto the resist-blasted ceramic object with a paintbrush. Our initial assumption was that the conductive ink will adhere to the rough surface of the sandblasted traces and excess ink can be wiped off the glossy glazed surface, resulting in a clean inlaid conductive trace.

However, the inks we used dried rapidly once applied and stayed on the glazed surface (Figure 7B), even when thinned with a paint solvent. We then investigated alternative methods of removing the ink—and discovered that the excess conductive ink could be easily removed with scrapers already used in ceramic crafts. The scraping process removes ink on the glazed surface of the ceramic object,

Table 2: Conductive inks used in this research.

Brand and Product	Conductive Material
MG Chemicals 838AR	Carbon
MG Chemicals 841AR	Nickel
MG Chemicals 842AR	Silver

while avoiding the ink in the recessed sandblasted traces (Figure 7C). This also implies that the inlaid conductive traces can resist external wear. However, it is important to note that the scraping process works best on surfaces coated with high temperature vitreous glazes. We observed that conductive ink adheres too strongly to softer coatings and scraping easily damages these less durable surface coatings.

Upon settling on the technique to apply conductive inks, we began measuring the conductivity of the circuit traces. Silver ink exhibited the lowest electrical resistance, followed by nickel, then carbon paint. It was challenging for us to achieve consistent electrical resistance across similar traces due to the manual painting process. As with conventional electrical traces, increasing the cross section area of the trace lowers the electrical resistance of a trace. This was effectively achieved by increasing the depth of the trace or increasing the number of coats of paint. We observed that increasing the width of the trace does not reliably reduce the electrical resistance of a trace. Wider traces (while larger in cross section area) exacerbate the hand painted inconsistencies of conductive ink, which is further compounded by the rough ceramic surface. With this in mind, we avoid designing circuit with wide traces of large patches. We systematically documented our empirical measurements for the electrical resistance of conductive traces in the conductive trace swatch document (Figure 11).

4 EXTERNALIZING THE APPROACH

We assembled the insights from our material exploration into a systematic approach for working with resist-blasting and conductive inks to incorporate conductive traces into glazed ceramic ware. We externalized these findings for other designers and researchers through an annotated flowchart of the process, as well as annotated swatches for resist-blasting and conductive traces.[1]

[1]We also provide these documents through video and high resolution files in the supplementary materials.

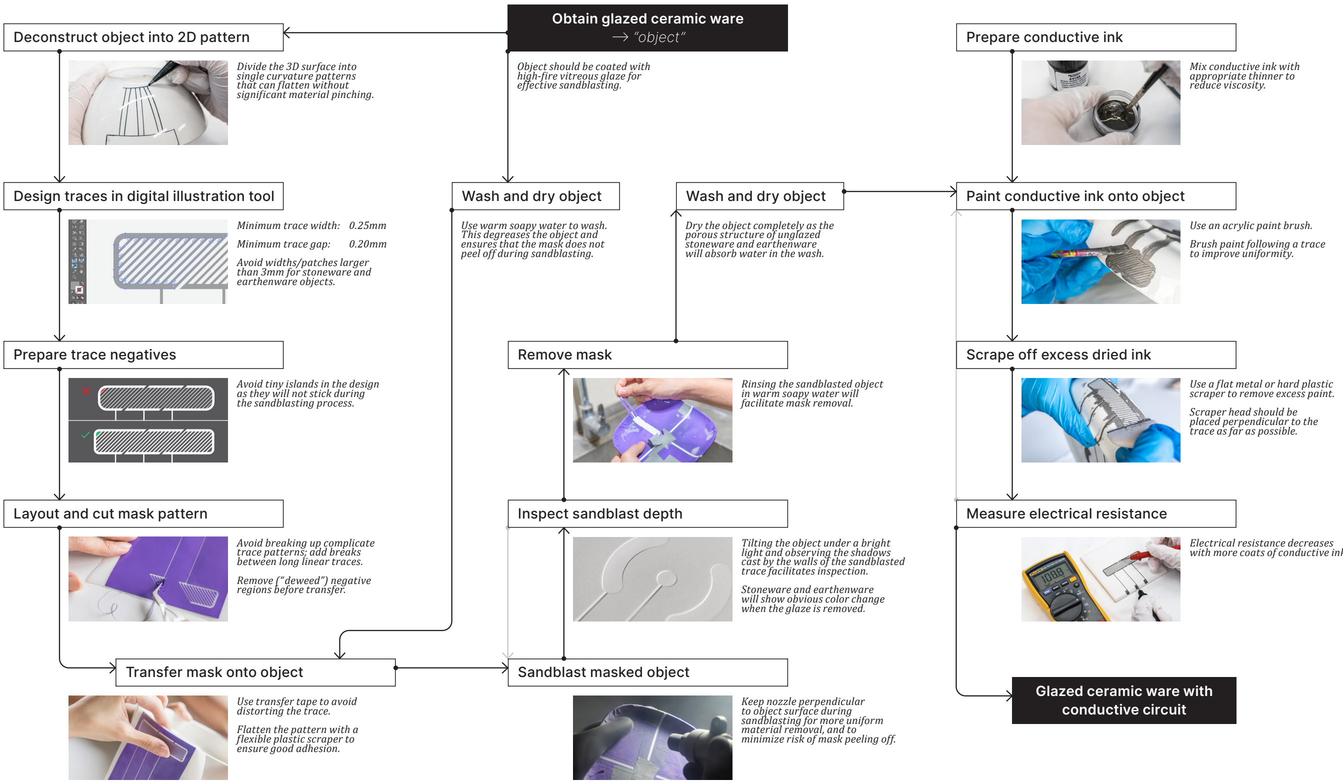

Figure 9: Annotated Flowchart: Capturing the specific sequence of steps and details behind instrumenting glazed ceramic ware with circuits via resist-blasting and conductive ink.

4.1 Annotating the Approach Step-by-Step

While the overall approach we developed appears straightforward at a glance, there were many small details peppered throughout the whole process that are critical for a successful outcome. Some details came from the tacit knowledge [37] that Hans Tan acquired while developing the resist-blasting technique, which we inherited by adopting the technique. Other details came from our material exploration (section 3) in resist-blasting and conductive inks for interactive circuits.

We created an annotated flowchart (Figure 9) to capture this specific sequence of steps in our approach, as well as the important guidelines and tools in each step. We also provide visual reference for each step in this flowchart.

4.2 Glazed Ceramic Swatches

Swatches are physical samples that document and convey specific information about a particular material practice; for instance, textile squares for garments, surface finishings for counter-tops, or color samples for print. HCI researchers proposed leveraging swatches as a new format to communicate research that “embeds and embodies computing in the physical world” [36], following the successful use of such artifacts to share material-driven research for e-textiles (e.g. [17]). We are inspired by this mode of communicating research findings—and leveraged swatches to highlight our material insights surrounding the resist-blasting technique and inlaid conductive traces made from our approach.

4.2.1 *Resist-Blasting Swatch.*

We used a small dining plate to make a resist-blasting swatch (Figure 10). This plate was manufactured in stoneware coated with a white glaze, which results in a distinct color difference between the glaze and underlying ceramic (Figure 4D).

At the center of the plate we arranged a radial pattern of lines. We varied the width of the sandblasted traces on one side; and on the other side, we varied the width of the gap between sandblasted traces. From this experiment, we observed that resist-blasting maintains gaps as small as 0.2mm. However, resist-blasting could only penetrate traces with widths larger than 0.25mm.

We covered the surrounding space with a series of patterns to experiment on. Each pattern was individually sandblasted based on two parameters: distance from the sandblast nozzle and duration of sandblast exposure. We used two types of patterns to highlight different resist-blasting features—a round region to highlight sandblasting spread, and an arcing trace to highlight the sandblasting effect on varying widths. These patterns reveal two important insights about the consistency of resist-blasting: 1) Material removal is most aggressive at the center of the nozzle and tapers off; sandblasting further away from the object results in slower but more consistent material removal. 2) Material removal occurs more rapidly on a thick trace than a thin trace.

4.2.2 *Conductive Trace Swatch.*

We used the same type of plate to make a conductive trace swatch (Figure 11). This plate systematically catalogs conductive traces in terms of depth (shallow vs. deep), trace width (0.5mm to 1.5mm), and type of conductive ink (carbon, nickel, silver). We also demonstrate how a continuous conductive trace might wrap over the rim of the plate from front to back.

This plate reveals the texture of conductive traces and how they are inlaid into the sandblasted tracks. We measured the electrical resistance of each trace and labeled them in the swatch document. The individual measurements highlight the inconsistent electrical resistance between similar traces due to manual painting. However, the overall measurements indicate the consistent effect that trace depth has on electrical resistance—shallow traces exhibit higher resistance, while deeper traces (and therefore a bigger cross section area) exhibit a lower resistance.

Glazed ceramics can be etched with a laser cutter. Although this process is out of the scope of the exploration in this work, we documented laser etched traces on the same plate as a comparison and as a prompt to inspire future work. From this plate, as well as other laser etching experiments, we observed that the laser cutter is less effective at removing material compared to sandblasting—and was not able to completely remove the glaze. Furthermore, while this digital fabrication process removes the need to mask an object, it is only able to work on flat pieces.

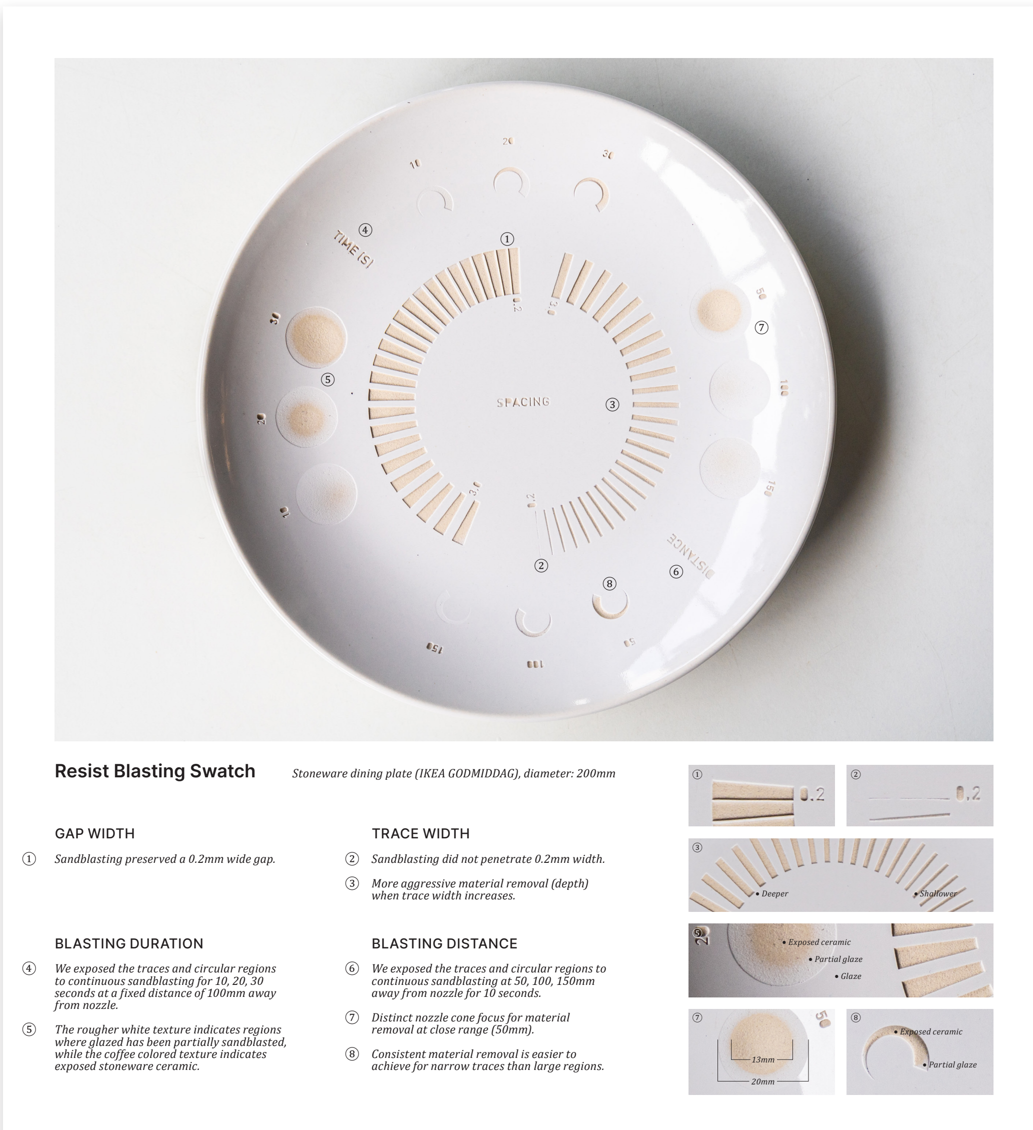

Figure 10: Resist-blasting swatch annotated with the results of different sandblasting experiments that probe sandblasting in relation to distance, duration, trace width, and trace gap.

Conductive Trace Swatch

Stoneware dining plate (IKEA GODMIDDAG), diameter: 200mm, trace length = 30mm, all units in Ohms

	SHALLOW *(partial glaze removal)*				DEEP *(complete glaze removal)*			
Trace Width *Ink Type: Nickel*	① *0.5mm*	1227	499	572	④ *0.5mm*	42	36	39
	② *1.0mm*	332	271	297	⑤ *1.0mm*	38	18	20
	③ *1.5mm*	389	156	254	⑥ *1.5mm*	8.0	8.5	8.3
Ink Type *MG Chemicals*	⑦ *Silver*	2.1	1.6	2.1	⑩ *Silver*	1.0	0.6	0.5
	⑧ *Nickel*	78	97	137	⑪ *Nickel*	30	16	17
Carbon: 838AR *Nickel: 841AR* *Silver: 842AR*	⑨ *Carbon*	31500	46980	33240	⑫ *Carbon*	8560	7790	8000

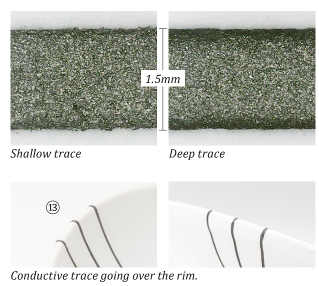

Figure 11: Conductive trace swatch annotated with the electrical resistance measurements of inlaid conductive traces that vary in terms of depth, width, and ink type.

5 IMPLEMENTING INTERACTIVE RESIST-BLASTED CIRCUITS

Building on top of the approach we developed, we explored how to shape conductive traces on glazed ceramic objects into functional and interactive circuits.

5.1 Laser Cut Analogs

We found that we could rapidly etch circuit traces on acrylic sheets with a laser cutter and apply conductive ink into these traces using the same process as resist-blasted ceramics. We used such laser cut analogs to rapidly test and refine different parameters of an interactive circuit before committing to ceramic ware (Figure 12A). For instance, we used laser cut pieces to systematically test small variations in trace width, length, and distance for capacitive touch sensors till we found a set of parameters that worked reliably.

The laser cut pieces also served as a mediator between physical and computational materiality, revealing issues that were difficult for us to perceive. For instance, we discovered that the uneven heating across a heating element was due to the inconsistent resistance along the length of the conductive trace (Figure 12B). By trying out different conductive paints (Table 2), we concluded that the silver paint had the most consistent electrical resistance when manually applied, and was the better conductive material for crafting heating elements with our approach.

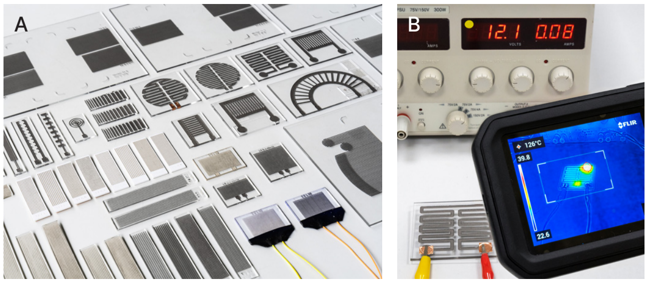

Figure 12: A: Trying out different circuits on laser cut acrylic pieces. B: Heating element circuit on laser cut acrylic with inconsistent electrical resistance, resulting in uneven heating.

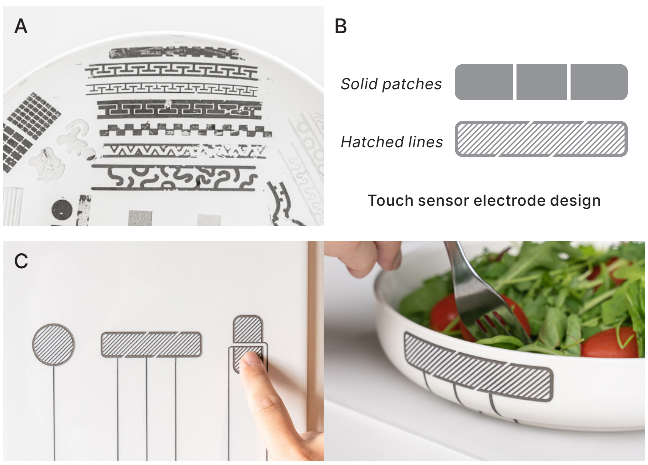

Figure 13: A: Initial trace designs. B: Modifying touch sensor electrodes from solid patches to hatched lines. C: Applying "hatched lines" as a visual language onto different objects.

Table 3: Circuit types that we investigated and their working principles.

Function	Working Principle
Touch Sensing	Senses change in capacitive discharge when bare skin comes close or contacts an electrode. e.g. [18]
Moisture Sensing	Senses the change in resistance between two electrodes due to ions dissolved in water. e.g. [50]
Temperature Sensing	Senses the increase in resistance for a conductive trace when temperature increases. e.g. [7]
Resistor	Varying trace length changes the overall resistance of a circuit segment. e.g. [55]
Heating element	Electric current is converted to heat as it passes through a conductive trace. Amount of heat produced depends on the resistance of the trace and power supplied. e.g. [11, 46]

5.2 Designing Interactive Traces

We took inspiration from interactive circuits demonstrated by related work in HCI, and translated them into circuits that we can fabricate on glazed ceramic ware (Table 3).

Resist-blasting offered a high degree of control in terms of the visual appearance of the circuit. Our initial interactive trace designs explored the many possible forms of interactive interfaces that we could etch with sandblasting (Figure 13A). As our exploration progressed, we balanced the visual appearance of the interactive circuits with the constraints of the materials and processes involved. For instance, we modified the electrode design of a capacitive touch sensor from a solid region to a series of hatched lines (Figure 13B) to avoid the inconsistent electrical resistance demonstrated by wide conductive patches (subsection 3.5). This "hatched lines" design became a visual language that we applied to other types of circuits and applications (Figure 13C).

5.3 Physical Computing System

The glazed ceramic circuits, sensors, and transducers require additional electronic components such as a microcontroller and power supply to function as a physical computing system. We used an *Arduino Uno R3* as the microcontroller unit for all sensing examples demonstrated in this paper. This microcontroller communicated sensor data over a USB serial connection. We used an *MPR121* breakout for capacitive touch sensing, and a voltage divider circuit for resistive sensing. We used a current-limiting bench power supply to power and control the heating element circuit. We used conductive fabric tape soldered to a silicone jumper cable to interface between the conductive pads on the glazed ceramic prototypes and the broader physical computing system (Figure 14).

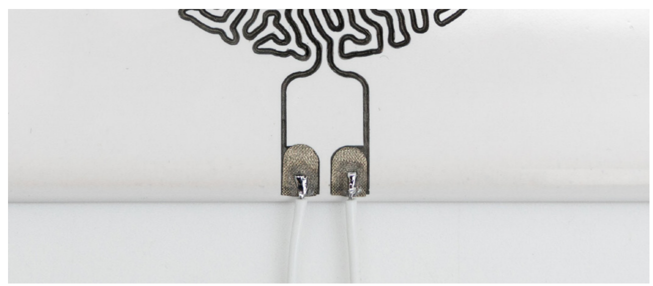

Figure 14: Conductive fabric connections.

5.4 Circuit Swatches

We consolidated the interactive circuits we explored into a series of interactive tiles. These tiles encapsulate the working principle of each electronic circuit, and they also demonstrate specific circuit forms that we designed to suit each electronic function. We detail each interactive circuit in the circuit swatches document (Figure 15) along with their individual schematics and vector drawing files.

Capacitive Touch Slider (Figure 15A): The touch slider comprises a conductive rectangular bar split into three distinct regions. Each region is connected to a capacitive touch detection channel with a *MPR121* breakout. With three channels, we were able to approximate the location of touch along the bar, as well as detect swiping gestures along the bar by computing the sequence of touch events.

Resistive Temperature Sensor (Figure 15B): The electrical resistance of a metal increases when its temperature increases and thermistors use this phenomena to sense temperature. We developed a space packing script to condense a 2.3 meter long trace into a 70 mm wide circle. This long trace amplifies the change in resistance due

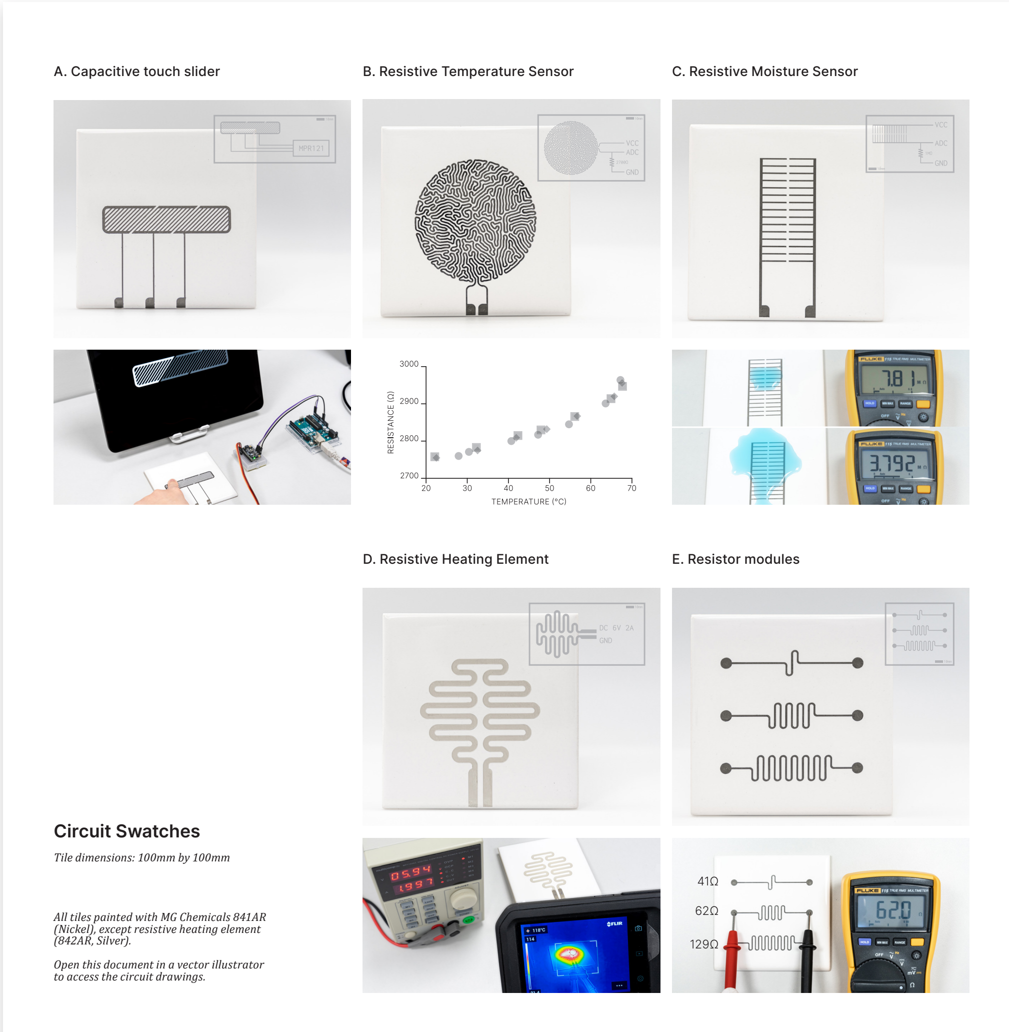

Figure 15: Five circuit swatches accompanied with their respective circuit schematics and working demonstrations.

to temperature and is easily read by a microcontroller and a voltage divider circuit.

Resistive Moisture Sensor (Figure 15C): The water sensor comprises two electrodes that come into contact with moisture. The electrical resistance across the electrodes decreases when contact with moisture increases. We can detect this change in electrical resistance with a voltage divider circuit to approximate the amount of moisture contact.

Resistive heating element (Figure 15D): We devised a simple resistive heater that produces heat when a current is applied. We kept the design of the trace simple to minimize the variation of electrical resistance along the length of the trace—which results in more uniform heating throughout the whole circuit. The specific heating element we fabricated has an overall trace resistance of 3.0 Ohms, and heats to 110°C with 12 watts of power (6V and 2A).

Resistor Modules (Figure 15E): This swatch contains three conductive traces of different electrical resistance values, following the same trace design used in [50]. Such traces might be used as a constant resistor for voltage divider circuits, or to identify objects through unique resistance values.

6 APPLICATIONS

From the approach we developed to craft conductive traces on glazed ceramic objects (section 4) as well as the range of functional circuits that we investigated (section 5), we designed and built a range of functional prototypes for a variety of applications. We built these prototypes with two design goals in mind:

First and foremost, we wanted to demonstrate the capabilities of the approach for crafting functional, three-dimensional, and intricate interactive circuits on existing glazed ceramic ware. In the applications we built, we used a range of ceramic objects—from flat

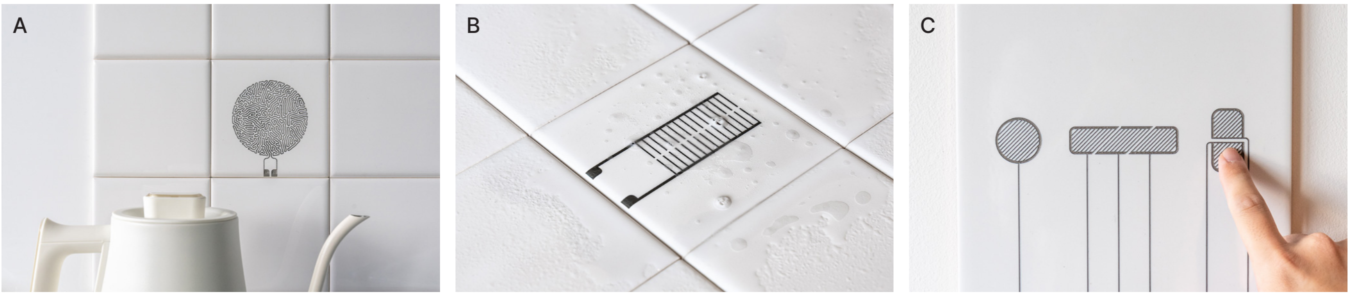

Figure 16: Interactive tiles. A: Temperature sensing tile installed into a kitchen. B: Moisture sensing tile installed into a bathroom floor. C: Touch control panel with three types of inputs.

tiles to vessels of different forms. We crafted complex conductive traces that wrapped around the surface of these objects, and connected these instrumented artifacts to external microcontrollers and visualized them working.

Second, we wanted to probe the potential of our approach to create interfaces specific to a particular context. In this paper, we focused on interfaces for the home context. The home context served as a "most-focused" filter [23] for the prototypes, as our familiarity with these spaces enabled us to consider use cases that center our first-person, everyday experiences. We took reference from related work that deployed decorative interactive systems in the home (e.g. [24, 25, 27, 28]). For each prototype, we carefully considered the physical form and practical uses of the ceramic objects we were working on—and crafted circuits that were functionally and aesthetically integrated into each artifact. We then used these prototypes as "manifestations of design ideas" [23] and discuss the home applications that they inspire.

6.1 Interactive Tiles

Glazed ceramic tiles provide a sanitary, waterproof, and heat resistant layer of protection for living spaces, and are commonly used to clad bathroom and kitchen walls. In prior HCI work, researchers have demonstrated using thermochromic ink on instrumented acrylic tiles to provide visual feedback on ambient heat and detect touch interactions [28]. We extend these use cases to glazed ceramic by reframing the interactive circuit swatches we developed (Figure 16) as interactive and decorative elements that are integrated into the surface of a wall. For instance, we can integrate temperature sensors on the back wall of a kitchen stove (Figure 16A) to monitor if the stove is in use (or if there is a fire); or moisture sensors on the bathroom floor (Figure 16B) to detect if a shower is running (or leaking). Touch interfaces can also be integrated into wall tiles (Figure 16C). We propose that such interfaces may replace conventional mechanical interfaces to control home systems such as lights or air conditioning.

6.2 Post-screen Interface: Touch Screen Extension

Continuing the series of tile-based interfaces, we explored extending the touch sensing capabilities of a smartphone screen with conductive traces on a flat ceramic tile, building on top of the working principle demonstrated in [20]. From this investigation, we developed a smartphone docking tile with conductive traces that extends the phone's touchscreen interactions when it is placed face-down on the tile (Figure 17A,C). This tile is unpowered, and works by extending the capacitive sensing capabilities of the device's screen to other regions on the tile through conductive traces. Bare skin contact with these regions triggers a touch event on the phone's screen. We developed a visualizer running on the phone's web browser to demonstrate the capabilities of this interface to transmit multi-touch gestures to the phone.

We propose that this minimal and screen-free interface could offer a mindful option [45] for people to interact with existing phone applications without interacting with the phone—such as controlling connected devices around the house.

Figure 17: A: Smartphone docking tile that extends the touchscreen's sensing capabilities. B: Web visualizer demonstrating the touch screen extension capabilities of the tile. C: Empty smartphone docking tile.

6.3 Interactive Vessels

Ceramic vessels are commonplace in many homes, and HCI researchers have leveraged these rich objects to engage in material speculation for design research [24] and slow technology [27]. We were similarly inspired by these vessels, and considered how they might be designed to support the everyday activities that take place in and around them.

We instrumented a series of everyday ceramic vessels for sensing and heating, including a set of dining ware and a plant pot (Figure 18). These artifacts required us to fabricate circuits that wrap

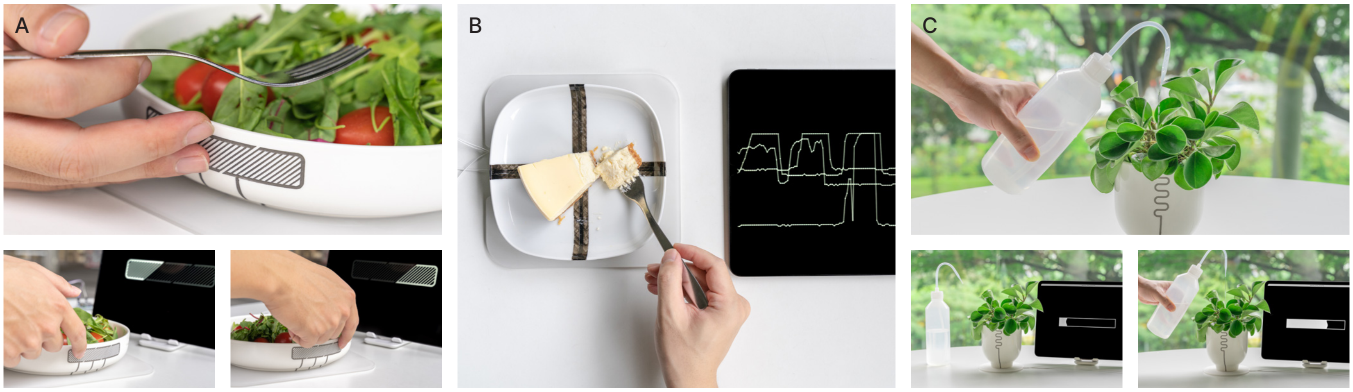

Figure 18: Interactive ceramic vessels. A: Salad bowl with touch slider along the bowl's side. B: Dining plate with four sensing traces that are triggered by a metal utensil. Each trace is insulated with food safe porcelain paint. C: Plant pot with integrated sensor that detect soil moisture levels.

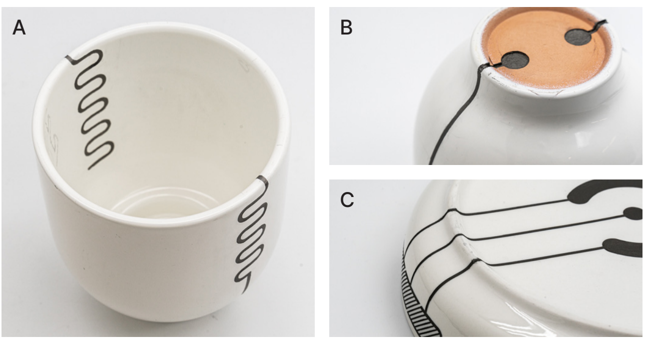

Figure 19: Circuits wrapping around the complex three dimensional surface of existing ceramic ware. A: Over the rim of a plant pot. B: Over the edge of the plant pot's base. C: Over the edge of the salad bowl's base.

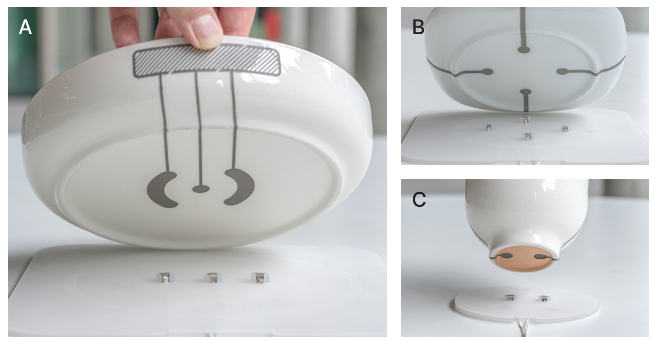

Figure 20: Acrylic placemats with conductive silicone pads that interface with each interactive ceramic vessel. A: Salad bowl placemat. B: Active dining plate placemat. C: Moisture sensing plant pot placemat.

around the form of the object, including the outer and inner surfaces, as well as rims and edges. Besides interactive function, these vessels also showcase the capability of our approach for creating complicated three dimensional circuits (Figure 19).

The electronic elements on these vessels require an external microcontroller and power supply to complete the functional circuit. To facilitate this, we developed a system of "placemats" with soft silicone pins lined with conductive fabric (Figure 20). These pins are arranged to press against the conductive pads at the base of the vessels ensuring good electrical contact. Wires carrying the electrical signals from the silicone pins run beneath the placemats to an external microcontroller, keeping the immediate area surrounding the vessel clean to facilitate everyday activities.

6.3.1 Salad Bowl with Slider. We took the same capacitive touch slider design (Figure 15A) and applied it to the side of a porcelain salad bowl (Figure 18A). The recessed traces of the slider on the surface of the bowl offer subtle tactile feedback during interaction. We developed a *Processing*[2] visualizer to indicate touch events that occur along this slider. This system detects discrete touch events on each individual region on the slider, as well as sliding gestures by computing the sequence of touch events that occur. We propose that such interfaces could be connected to the smart home network and serve as an alternative means of controlling other home devices during mealtime (such as music or lighting systems).

6.3.2 Active Dining Plate. We instrumented the eating surface of a porcelain side plate with four capacitive sensing traces (Figure 18B). Food-safe porcelain paint was applied on top of these traces to prevent food from coming in direct contact with the conductive trace. These traces are able to sense the proximity of metal utensils in use (e.g. cutting a cake with a dessert fork). We developed a *Processing* visualizer that renders the capacitive touch readings of each trace. The readings across the four channels vary as a metal utensil moves around the plate during the meal, and these readings can therefore be used to approximate eating activity. We propose that such plates could serve as an interface for monitoring eating activity or for playful mealtime interactions—supporting human-food interaction scenarios previously discussed in HCI research (e.g. [21, 27]).

6.3.3 Heated Dining Plate. We applied a heating element to the bottom of a small plate (Figure 21). This plate is able to reach a top surface temperature of 105°C when supplied with 30W of power (12V and 2.5A). Such plates can be used to keep food warm during meal service, and we demonstrate its heating capabilities by cooking a raw chicken egg. We used cork sheets as the placemat material in this application for better heat resistance.

[2]https://processing.org/

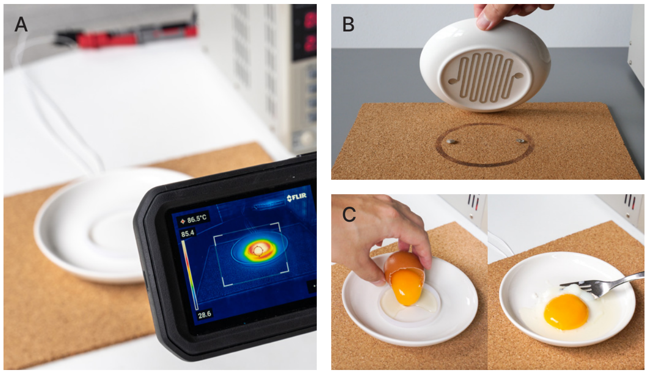

Figure 21: Small plate with underlying heating element that is capable of cooking a raw egg. A: Plate heating up. B: Heating circuit on the base of the plate. C: Cooking a raw egg.

6.3.4 Moisture Sensing Plant Pot. Besides dining applications, we also looked into caring for houseplants (Figure 18C). We applied a moisture sensor to the inner surface of a small plant pot. The moisture sensing electrodes are placed on opposite sides, and each sensing electrode wraps around the outer surface to the base of the pot where it connects to the placemat (Figure 19A,B). We use this sensor to approximate the overall moisture level throughout the soil in the pot by measuring the change in resistance between each electrode. We render the sensor reading on a *Processing* visualizer through a simple bar that indicates the soil's moisture level.

7 DISCUSSION

We reflected on our material exploration and the artifacts we built, and discuss what we learnt from crafting interactive circuits on glazed ceramic objects as well as further work for continuing this research. We also reflected on our process of engaging with the materiality of glazed ceramic ware for interaction design, along with our partnership with an expert craftsperson, and discuss this experience within the broader conversation of crafting as a mode of HCI inquiry.

7.1 What Our Prototypes Revealed

Prototypes serve a generative role in the design process. Lim et al. [23] proposed two dimensions to frame the role of prototypes: First, prototypes can act as filters to help focus on a particular aspect of design. Second, prototypes can act as manifestations of design ideas to realize ideas in the real world. As both filters and manifestations of our approach and ideas, the prototypes we built revealed new concerns for crafting interactive circuits on ceramic objects that we had not considered before.

7.1.1 Electronics Infrastructure. While beyond the design goals that we set, the application prototypes—as functioning electronic systems—revealed larger infrastructural needs that we need to address in order for these systems to be properly integrated into the home context. For example, while the acrylic placemats were a clever way to connect the vessel to a microcontroller, vessels had to be carefully placed so that their conductive pads align with the pins on the placemat. In addition, we were using a basic microcontroller (Arduino Uno R3) to parse the signals from the ceramic sensors, and sending these signals to a laptop computer for network communication and visualization. While this served as a convenient setup for a *research prototype*—it is certainly too cumbersome for long term interactions with these interactive objects as *research products* [31]. These gaps point us toward practicalities to consider for future work. We are inspired by platforms like *Lilypad* [5], *Chibitronics* [2], and *Bare Conductive* [1] that provide extrinsic hardware support for incorporating electronics into physical crafts surrounding textiles and paper. Similarly, we see an opportunity to develop specialized hardware components such as networked microcontroller breakouts and electrical connectors that work with the interactive ceramic objects built with our approach. We also see an opportunity to extend our collaboration to interior designers, builders, and electricians to explore how ceramic interfaces and the electronics infrastructure they require can be integrated into the construction of our living spaces. Such components and processes will enable us to build higher fidelity systems that facilitate long term and real life engagements with these artifacts.

7.1.2 Upkeeping Interactive Ceramic Artifacts. Our approach supported the construction of ceramic artifacts that can withstand everyday use. Notably, the recessed nature of the conductive traces meant that they could be easily cleaned without damaging the circuit (Figure 22). Beyond these short term engagements with the artifacts, we also considered the longer life cycle of these electronic ceramic interfaces. In this regard, we were challenged with working with things that were inherently prone to breakage; and indeed, we broke a plate during the course of our research that we spent a good amount of time working on. This led us to reflect on issues surrounding the sustainability and end-of-life for computational devices [4, 43, 53]. We were reminded of the *Morse Things* project and how it commemorated broken prototypes through *kintsugi* repair [32]. Breaking our prototype provokes us to consider how we might repair, restore, or renew the interactive ceramic devices that are built from our approach. Coincidentally, these are themes that Hans Tan addresses in his work as well, albeit in the field of decorative arts instead of HCI. We see an opportunity to extend our work beyond crafting tangible interfaces with resist-blasting—and consider how adjacent repairing practices might participate in upkeeping interactive ceramic artifacts.

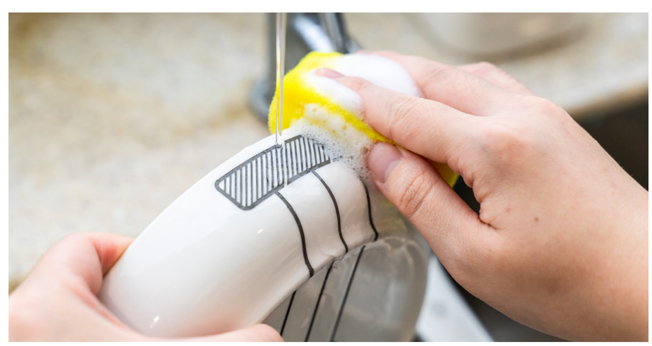

Figure 22: Cleaning a prototype with a dish sponge.

7.2 Emerging Values of Collaborating with Craftspeople in Material Centered Design

In Table 1 we identified a collection of projects in HCI that inspired us in the sense that they served as a bridge between materialities and techniques well known in established craft practices, repurposed for interactive application. These examples illustrate not just different outcomes for interactive systems, but different processes to unearth new design trajectories. We viewed each of these projects, whether explicitly described as material-driven design or not, as exemplars of materials-driven design that center the knowledge of practitioners in a field outside of HCI—by either training themselves deeply in that knowledge or collaborating with expert craftspeople in those domains. Collaboration, here, describes a mutually beneficial relationship, whereby craft and technical knowledge are placed on equal footing and parties derive mutual benefit, as described by Devendorf et al. [10]. Thus, we adopted a similar approach and partnered with an expert ceramics craftsperson and his individual craft practice—and sought to be guided by "something that may come from within the materials, a form that we tease out of those materials as we allow them to have their say in the structures we create" [8, p.14–21].

While each domain may be different (from e-textiles to paper-craft) we see this body of bridging work emerging from a shared set of collaborative practices which both inspired and resonated with our practice. With this in mind, we add to this discourse of craft collaboration in material-driven design in the following sections by articulating the unique benefits that emerged (for both the interaction design team and craft collaborator) though the project we describe in this paper.

7.2.1 Centering the Tools of Craftspeople Bridged Craft and HCI. In this research, we made a conscious effort to keep the processes and tools we explored as close to the ceramics workshop as possible. Our close collaboration with Hans Tan was essential to this work. Collaborating with a ceramics craftsperson was a way for us to have a proxy in a material practice we were not yet familiar with. We, then, were a proxy for the material practice of physical computing; understanding what would be required for achieving various functional effects. As discussed by Frankjaer & Dalsgaard [12], we found ourselves moving between "localized points of interests" between the "material landscape" of glazed ceramic ware and physical computing—seeking to open up paths *between* Hans Tan's practice in ceramics *and* our practice in making interactive systems.

This led us to new tools and processes that we had not considered before for enabling physical computing on glazed ceramic ware. As a notable example: we did not expect conductive paint to dry so rapidly, which disrupted our initial assumption of wiping excess ink off as a liquid. In closely assessing and experimenting with the dried ink on the glazed ceramic surface, we discovered that we could scrape it off cleanly. The approach we were developing took an alternative route—and one that was more viable and relevant to the materials present. When we made a trip to the crafts supply store to source for the appropriate scraper, we were greeted with a whole suite of scraping implements that ceramic crafters already use as part of their process.

This partnership helps us understand the HCI practice we took in this work as one that centered the established modes of ceramic craft in the production of new interactive possibilities. This practice both illuminates a new approach to circuits, as well as the relevance of "old" craft to present day innovation. We hope that the productive partnership we forged between ceramic crafts and HCI will contribute to how we (as a research community) consider incorporating computational technology into everyday life such that "value flows in all directions" between new and existing object systems [34].

7.2.2 Drawing from Resist-Blasting. The process we took is inspired by prior work in HCI where researchers collaborate with craftspeople for the production of interactive artifacts; such as in leather-working [47] and ceramics [9]. Our research further the forms of such collaborations by highlighting the potential of partnering with *an individual and their unique craft practice* for creating interactive systems; alongside learning and extracting general techniques used in a particular realm of craft.

The work we present in this paper goes beyond simply shaping conductive paint on a ceramic surface. We investigated the double-layer composition that glazed ceramic objects offer, and the affordances of this physical structure for functional electronics. A large part of our exploration revolved around the specialized resist-blasting technique developed by Hans Tan. We sought to "align and integrate" [12] this crafting technique with the physical computing principles that we were familiar with to build functional interactive systems. Exploring physical computing through the lens of the structure of glazed ceramic objects and a subtractive fabrication process revealed many new affordances for electronics.

Most crucial to our approach—resist-blasting enabled intricate traces to be etched onto the three dimensional surface of the ceramic artifacts. It exposes the rough ceramic body as a suitable substrate for receiving conductive paints, and preserves the hard and smooth outer glaze to facilitate scraping off excess paint. Besides circuit construction, the structure of glazed ceramic also facilitated the operation of sensors and transducers. The waterproof glaze supports resistive moisture sensing by channeling water effectively to the electrodes (Figure 15C), while the thermal transmissivity of ceramic supports effective transfer of heat generated by the heating element through the walls of the object (Figure 21).

7.2.3 Contributing to Resist-Blasting through Computational Design. In collaborating with Hans Tan as an individual craft practitioner, we also found ourselves contributing back to his unique process of resist-blasting. To design the temperature sensing tile (Figure 15B), we developed a computational design algorithm to pack a long trace inside a small circular area. We were initially focused on maximizing the length of a trace to improve the sensor's response to temperature change. As we worked on this tile, we noticed that these computationally generated traces also facilitated other steps in the making process. The pattern, despite its complexity, was easy to cut with the *Cricut* machine as it consists of a single unbroken path. The branching coral-like traces provided the vinyl mask strong adhesion on the glazed surface to withstand sandblasting (Figure 24A). These same branches also facilitated efficient scraping of excess conductive ink (Figure 24B).

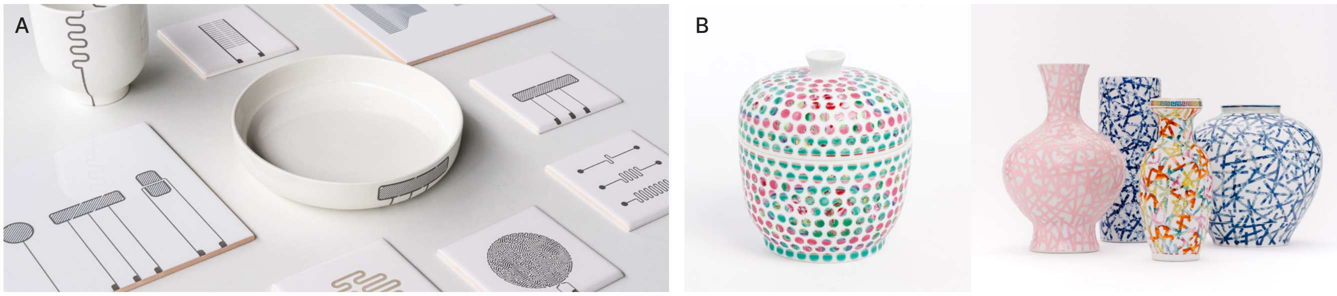

Figure 23: A: Collection of artifacts built in this research. B: Pieces from Hans Tan's design collection.

Designing and making the temperature sensor serendipitously revealed new insight into the masking process for resist-blasting that our craft collaborator had not considered before, broadening the range of patterns that can be created with the technique. This insight stemmed from a computational design process that generated patterns that would have been challenging for us (including the craftsperson) to conceive manually.

HCI researchers proposed that digital technology can broaden the expression of existing craft [16]. For us, the temperature sensor reveals one form of such productive partnership between traditional craft and digital design. It simultaneously demonstrates the role of computational design and fabrication in informing and widening a traditional craft technique, while also revealing the role of traditional craft plays as a context that gives real world meaning to explore these digital practices. We see more potential in this intersection of digital and traditional processes for crafting interactive systems, and aim to investigate other computational design algorithms and digital fabrication processes along with ceramic craft practices in future work.

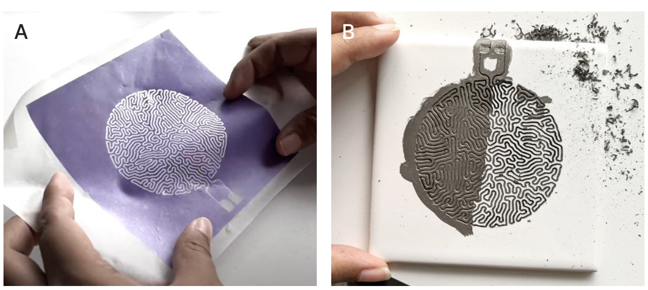

Figure 24: A: Transferring vinyl mask onto a ceramic tile for the temperature sensor. B: Scraping excess conductive ink off the temperature sensing tile.

7.3 Aesthetics & Speaking to Specific Audiences

We were certainly influenced by the craft traditions that our work is situated in; that places an emphasis on the aesthetics and finish of the things we built [12]. As a first account of this project, we were also conscious of designing and presenting our work in a manner that connects to the broader HCI community. Balancing these aesthetics concerns resulted in a consistent visual characteristic across the things we built: white ceramic objects inlaid with clean trace designs that resembled printed circuits (Figure 23A). Through this aesthetic decision, we hope to clearly communicate our findings on the new process of resist-blasted circuits for interaction design—and connect that to what HCI researchers might find familiar with regard to physical computing.

While we stand by our aesthetic choices, we do so with no small feeling of irony when we look at the colorful and intricate world of glazed ceramics (Figure 23B). As we consider future plans for this research, and how we present our work to different communities, we are interested to push the visual expression of resist-blasted circuits. For instance, we aim to develop a series of tangible interfaces with heritage ceramic ware, and craft circuit patterns that are inspired by the motifs found on these traditional objects. Through these pieces, we hope to further the conversation we started with this paper—examining not only what traditional processes have to offer, but also traditional objects and their possible roles as part of an interactive system. In addition, we plan to work with other ceramic craftspeople to design interactive ceramic interfaces from the ground up (instead of working on existing ceramic ware)—and investigate the forms of interfaces that might emerge from such an approach.

8 CONCLUSION

Each new approach for making interactive things broadens the range of materials and practices that participate in HCI and ubiquitous computing systems. In this paper, we offer a detailed process to instrument glazed ceramic ware with interactive circuits. To develop this work, we collaborated closely with a ceramic craftsperson and learnt from his practice of resist-blasting, which we then translated and used to apply conductive inks onto glazed ceramic ware. Through the process we discuss here, as well as the documents we provide, we hope to facilitate others to take on similar investigations, as well as inform further material-driven inquiries for the research community.

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