Castura: A Versatile Silicone Microtexture Fabrication Technique Using Laser-Engraved Micromolds

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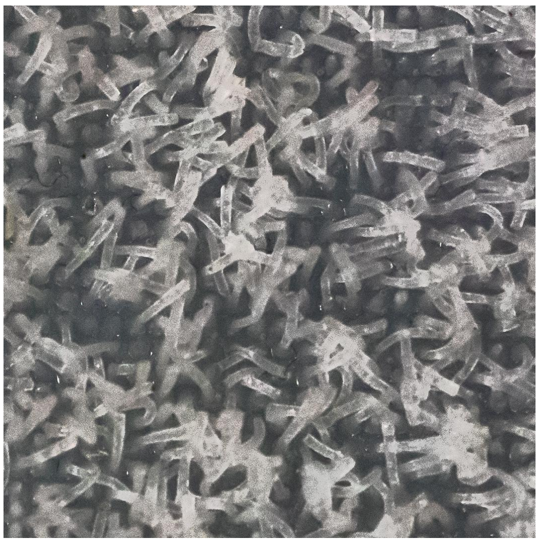

Figure 1: A close-up image of one of the more intricate and detailed microtextures produced via the casting technique; users perceived this texture as 3.25 soft/hard. and 3.00 smooth/rough (5 pt Likert scale).

Introduction

Microtextured surfaces are inherently useful for multiple different scientific and makerspace domains. This micro-surface topography can be leveraged to influence cell growth and behavior and mimic biological surfaces [8], or create microfluidic systems for micro-technology and fluid behavior studies [3]. Over the years, numerous methods have been developed in order to reliably fabricate these microtextures on metallic, plastic, and polymer surfaces for these investigations [1]. Despite this array of methods, there remains a demand for supporting reliable microtexture fabrication within academic makerspaces.

The Value of Microtextured Silicone

Silicone rubber is popular within the makerspace community due to its high tensile strength, heat resistance, electrical insulation, and flexible properties [5]. With these core features, the material is often adapted for haptic technology, soft robotics, or even wearables. Specifically, microtextured silicone is currently most commonly used in areas such as biomedical research, as the properties of the surface of this particular material can be manipulated to become more antibacterial, potentially making it more appealing for medical implants [4]. Due to these properties, as well as its common availability for purchase, silicone is a very approachable material to work with in the makerspace community. There is some hesitancy to work with the material, however, due to the wide variety of silicone available for purchase, the mess that can arise when working with it, and the proclivity to introduce air bubbles during fabrication.

Existing Fabrication Methods and Workspaces

Microtexture fabrication techniques are widely used in manufacturing scenarios. Metal injection molding (MIM) [2] is an additive process in which a textured nickel mold insert is placed inside of an injection molding machine to produce textured steel artifacts. Nanoimprinting lithography (NIL) is a similar process that utilizes imprint compression molding to create micro-trenches with a minimum depth of 100 nm [1]. On the other side of the spectrum, reactive ion etching (RIE) [1] and femtosecond laser ablation (FLA) [1] are two subtractive methods that use focused plasma or a laser to etch the desired topography into the material of choice. These fabrication techniques suffer from limited material application, low resolution, low throughput, or high production costs [1]; more critically, these techniques require high-powered machinery that are often restricted to research labs due to the high price to acquire and maintain them, or simply the sheer size of the machine.

Approachable Fabrication: Castura

Our work aims to develop a high-resolution microtexturing technique that leverages makerspace resources such as laser cutters, engravers, and 3D printers. Through iterative development, we refine our technique to improve reliability, versatility, and overall cost. To meet the criterion for an approachable, makerspace-friendly, effective, and low cost microtexture fabrication technique, we developed a method called *Castura* (a word-play on the latin origin of the word texture, *textura*). We specifically adapted the soft lithography micro molding technique [7] to be portable to makerspace equipment, common computer applications, and low cost materials to produce micro-textured silicone artifacts in a simplistic and mess-free way. This casting and stamping technique is also capable of creating a diverse variety of microtextures and texture sensations to be applied as desired.

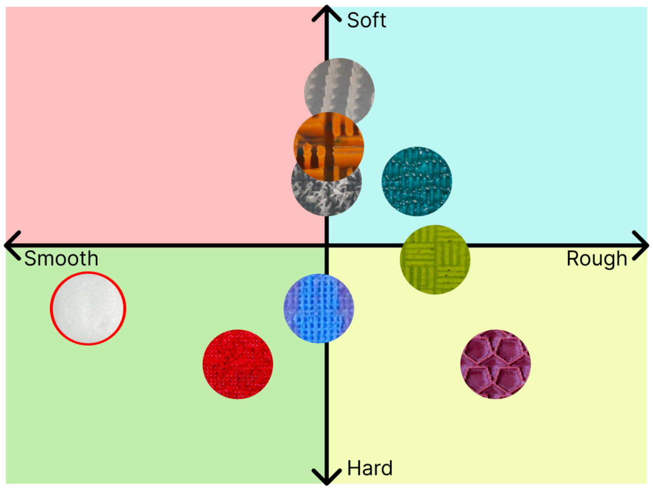

Figure 2: Types of Feel Perception reported by participants on 8 Castura fabricated textures. The sample with the red circle is untextured silicone.

Methods

Castura is a method for creating microtextured silicone by etching or cutting the inverse of a microtexture encoded as a scalable vector graphic (SVG) onto 3 mm acrylic using a laser cutter (80 watt; CO_2). This printing plate is then used as the base of a mold to support two different additive processes: "casting" and "stamping". For cutting textures with taller geometries (Figure 1), standard cut settings on the laser cutter is sufficient. However, when engraving for more depth-precise textures, the following settings are recommended: 600 dots-per-inch (DPI), 100% power, 100% frequency, 80% speed, and 6-8 cycles (depending on desired depth of the final geometry).

Casting

Casting is reminiscent of existing methods of the same name. The textured printing plate is used as the base to a mold in which the silicone mixture is poured into and left to cure, as seen in Figure 3B. This process is preferred when creating textures or small artifacts that need to be replicated easily or reliably; this is most notable for microfluidic applications, as the channels need to be consistent and often reproduced. The textures that are most efficiently produced are akin to the texture shown in Figure 1, often having a depth of 0.50 mm or higher. Both cut and etched plates are recommended for use with this method.

Stamping

The stamping method is reminiscent of the steps one might take when using a printing press. With a prepared sheet of silicone or scrap of fabric, the maker spreads a small portion of silicone onto the surface to act as a bonding agent for the texture itself. Then more silicone is carefully spread onto the printing plate, which is then pressed into the surface to transfer the desired texture, as seen in Figure 3A. This process is preferred when working with a larger canvas, as the maker does not have to worry about the laser cutter's size limitations, or for creating a unique material for wearables or experiments. This method is most effective for more simplistic texture designs, with a depth of 0.50 mm or lower. Etched printing plates are preferred when working with this method.

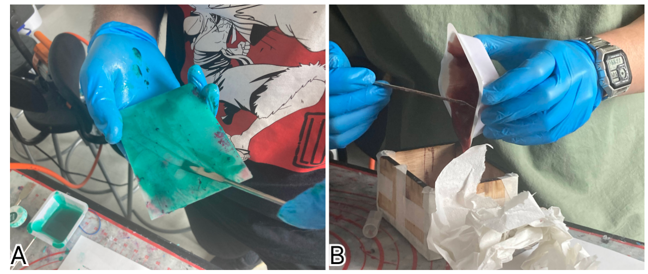

Figure 3: 3A shows a participant conducting the stamping method. 3B shows another participant conducting the casting method.

Evaluation

To ensure that these methods were approachable for makers, we conducted an informal between-subjects user study with four participants. Participants were provided with paper instructions and materials and tasked with producing a microtexture using one of the Castura methods. After the task, a questionnaire probed on the participant's making experience. Afterward, participants were presented with nine texture samples (Figure 2) and asked to rate them along two dimensions: "smooth/rough" and "soft/hard" [9]. In addition to the study, each texture was analyzed using microscopic imaging to assess for fabrication quality.

Results

Overall, the casting method was more successful, as the process meant that the inexperienced participants were able to create an artifact with little errors or mess (4 ± 0.0). In comparison, the stamping method was not as successful due to minor errors, but were not as substantial due to the instructions. Between all four, it was reported that the techniques were easy to follow, but did have a learning curve for new makers (4.25 ± 0.96). While gathering the data for the tactile perception field, it became evident that both methods were efficient at producing soft textures, an uncommon sensation for silicone. The responses also indicate that the techniques can generate a wide range of textures. Finally, after comparing the level-of-detail between the artifacts and the printing plates, we concluded that high-quality replications were produced.

Limitations

It is important to note that our presence during the informal study may have produced Hawthore effects and influenced participant's behavior and question responses.

Conclusion

Microtextures offer new avenues to explore cell properties or enhance the functionality of existing materials. However, fabricating them relies on expensive and complex machinery, limiting its access to the general public. To address this issue, we introduced Castura, a makerspace-friendly technique that leverages common machines and applications to produce microtextured silicone. By democratizing the fabrication process, Castura enables makers to engage in this field, fostering the growth of knowledge in the communities.

Acknowledgements

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