

Introduction

Xurography is a fast, low-cost method for prototyping microchannels, such as those used in microfluidics, by cutting thin films with a plotter. The term comes from the Greek xuro- “razor” and -graphy “writing.” While more precise fabrication methods exist, such as PDMS soft lithography, photolithography, micro-powder blasting, and laser ablation, they often require specialized equipment, longer fabrication times, or cleanroom facilities. Researchers have evaluated xurography as an alternative to these techniques (Bartholomeusz et al., 2005), demonstrating that it can substitute for processes including shadow-masking, electroplating, micromolding in PDMS, and fabrication of laminated microfluidic structures and ports. Additional work identifies xurography as a rapid, inexpensive alternative to photolithography for microfluidic device production, despite its lower resolution and material constraints (Shahriari et al., 2023), which supports its relevance in biomedical and diagnostic applications. These findings will support future particle-transport studies in microfluidic environments.

The purpose of this project is to evaluate how xurography can be used to optimize microfluidic channel performance from a bottom-up approach with food coloring by testing leakage, mixing efficiency, and thickness across different geometries.

Methods and Materials

The design process began by modeling microfluidic channel designs in Leonardo Design Studio Software. The designs were then sent to a Juliet 12” High-Definition Cutter. Thermoplastic sheets were cut and weeded off the cutting mat with a metal micro spatula. The sheets were then aligned and stacked on a stainless-steel block on a hot plate. An aluminum block was then placed above the sheets allowing them to be compressed, so the adhesion side of the sheets melted and fused together.

A test comparing the actual height to the calculated height of a stack of 14 three mil sheets was completed. The height of the stacks of sheets was measured using a Keyence VHX-7000 microscope and compared to the calculated heights of the devices across twenty trials. The null hypothesis stated that the mean actual height of the stack of 14 three mil sheets is equal to the calculated height of 1.0668 mm.

Leakage tests were run at different temperatures of fusion and assembly methods to evaluate how structural stability changed under different conditions. Colored dye was injected into the channels with pipettes, and photos were taken immediately and after one hour to show the coloring spread. The ideal conditions for assembly were evaluated to be 125 °C with an aluminum block above the channels to add pressure.

Methods and Materials (continued)

To accomplish this, colored fluid was inserted into the channels with a 90° bend, a 120° bend, and a circle in triplicate. Images were taken immediately and after an hour. The area from the photo of the device that was colored was determined by using ImageJ, binarizing the photo, and measuring the area of the black pixels. A percent increase was then calculated and compared across variations.

Mixing efficiency was evaluated by comparing a control of 50% red and 50% yellow food coloring in 300 µL of water to mixtures inside channels with a 120° bend, a zigzag, and a rectangle. Each channel was filled with water, and red and yellow food coloring were injected into different ports using syringes (Figure 1). After one hour, a photo of the channels and the control were taken (Figure 2). For each channel, the average RGB was obtained with ImageJ, and they were transformed into the CIELAB color space. Values of ΔE_{76} were obtained using the Euclidean distance formula relative to the control using ΔL , ΔA , and ΔB with measurements in triplicate. A smaller ΔE_{76} value indicates less change in color.

Figure 1 (right): Image of a 1.5” × 0.6” channel in the mixing test immediately after adding coloring. This initial image establishes the baseline color separation before any mixing or diffusion occurs.

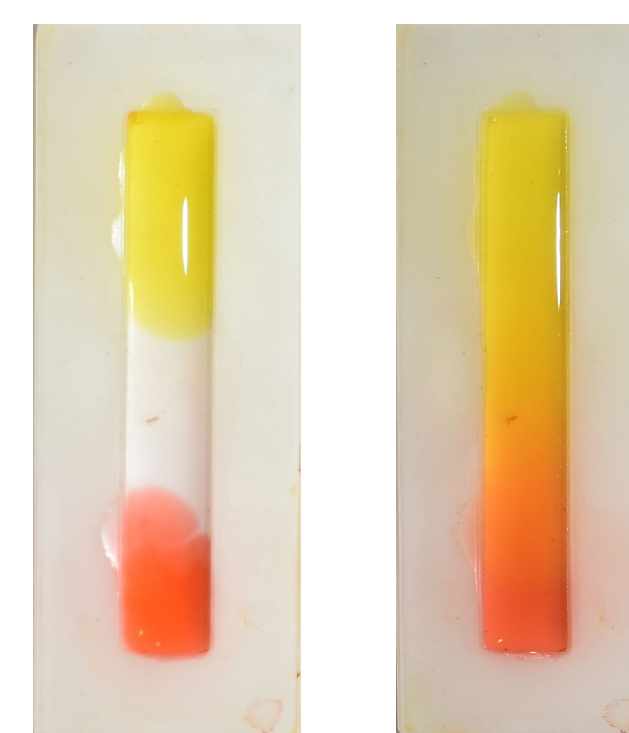
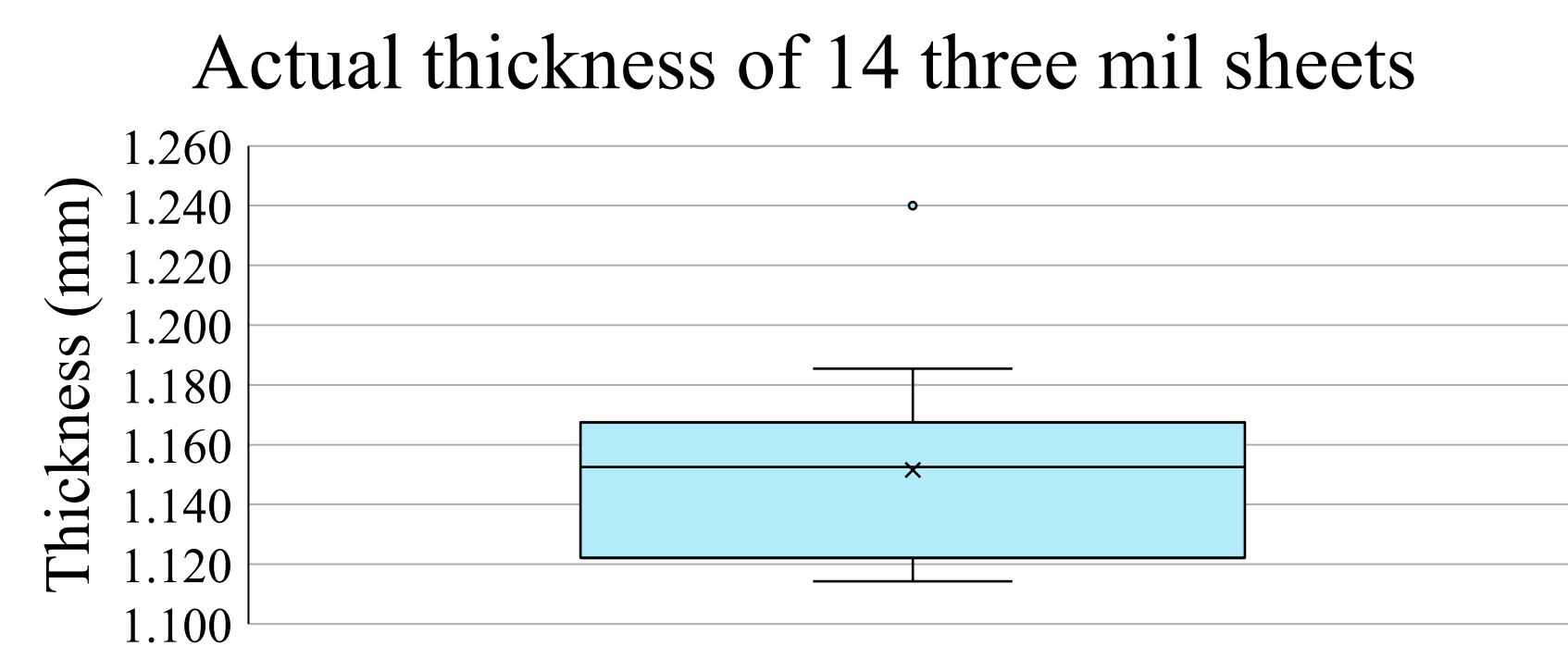


Figure 2 (left): Image of the same channel in the mixing test an hour after adding coloring. Over the course of an hour, the coloring diffuses throughout the entire channel.

Results

A one-sample *t*-test showed there was a significant difference between the expected calculated thickness of 14 three mil sheets at 1.0668 mm and the actual thickness of the produced sheets ($M = 1.1515$, $SD = 0.031$), $t(19) = 12.24$, $p < .001$. The mean difference in the thickness of the microfluidic channels was 0.0069 mm with a 95% confidence interval ranging from 1.1370 mm to 1.1660 mm. Using an alpha level of .05 the null hypothesis is rejected, suggesting that the actual thickness of the channels is different from the calculated thickness.



Graph 1 (left): A box and whiskers plot showing the actual thickness of different channels. The channels have a calculated thickness of 1.0668 mm.

Results (continued)

The 120° bend had the lowest percent increase in colored area, suggesting it was the most structurally stable shape. The rectangular channel had the lowest ΔE_{76} value, while the zigzag had the largest value, indicating mixing efficiency is greatest for rectangle channels.

Channel Geometry	Mean Initial Area (cm ²)	Mean Final Area (cm ²)	% Increase
Circle	2.62	2.86	9.21
Rectangle	2.54	2.70	6.25
90° Bend	2.49	2.70	8.48
120° Bend	2.52	2.61	3.90

Table 1 (left): The initial and final area of the coloring and a percent increase. The circle shows the largest increases, while the 120° bend shows the smallest.

Channel Geometry	ΔE_{76}
Rectangle	11.4
120° Bend	12.7
Zigzag	20.9

Table 2 (right): The color error (ΔE_{76}) was calculated using the standard Euclidean formula. The rectangle had the lowest error, followed by the 120° bend, and zigzag had the highest.

Conclusion

These results show that xurography can serve as a simple, low-cost method for producing functional microchannels. The results indicate that the adhesion from the films increases the thickness of the channels. The results also indicate that round channels leak the most. They also indicate that sharper channel angles tend to leak more and are less efficient at mixing like the zigzag channel, while larger angles mixed more efficiently. This trend likely occurs because sharper angles create dead zones where fluids can get trapped, which can reduce mixing efficiency and increase leakage risk. This is also due to the lack of boundaries in rectangular channels between the colors, allowing for rapid diffusion of the food coloring to mix. The findings from this project can be expanded upon by researchers in future chemical analysis, biomedical analysis like lab-on-chip testing of blood for pathogens, and to help monitor the environment. This project could be improved by taking more samples for the leakage and mixing tests to run a statistical test, using a more recent ΔE calculation like the ΔE_{2000} , and by using a camera with better resolution and better lighting for taking photos.

References

- Bartholomeusz, D. A., Boutté, R. W., & Andrade, J. D. (2005). Xurography: Rapid prototyping of microstructures using a cutting plotter. *Journal of Microelectromechanical Systems*, 14(6), 1364–1374. <https://doi.org/10.1109/JMEMS.2005.859087>
- Shahriari, S., Patel, V., & Selvaganapathy, P. R. (2023). Xurography as a tool for fabrication of microfluidic devices. *Journal of Micromechanics and Microengineering*, 33(8), Article 083002. <https://doi.org/10.1088/1361-6439/ace05d>