

Background & Motivation

Advancements in technology, such as the widespread adoption of lithium-ion batteries, introduce new risks to everyday activities. In electric vehicles, large battery packs can pose serious dangers during accidents or unexpected failures, increasing the need for research into flame-retardant coatings [1]. However, applying coatings to standardized test specimens, such as UL-94, is time consuming and difficult to reproduce consistently by hand [2]. While dip and spin coating offer automated solutions, commercial systems often cost over \$3000, provide limited opportunities for repair or modification, and often come with features not required by the end-user [3]. As a result, there is strong demand for low-cost, easily assembled dip and spin coating devices for clients such as the Bozlar Nanoscience Lab (BNL).



Specifications

Dip Coating Device

- 170 mm travel
- 0.1 mm/s minimum speed
- Specimen size as per UL-94 STD
- User Input & Feedback
- 120 VAC inlet with power switch

Spin Coating Device

- 500-8000 RPM
- 100 RPM increments
- 80 mm stage diameter
- User Input & Feedback

Results

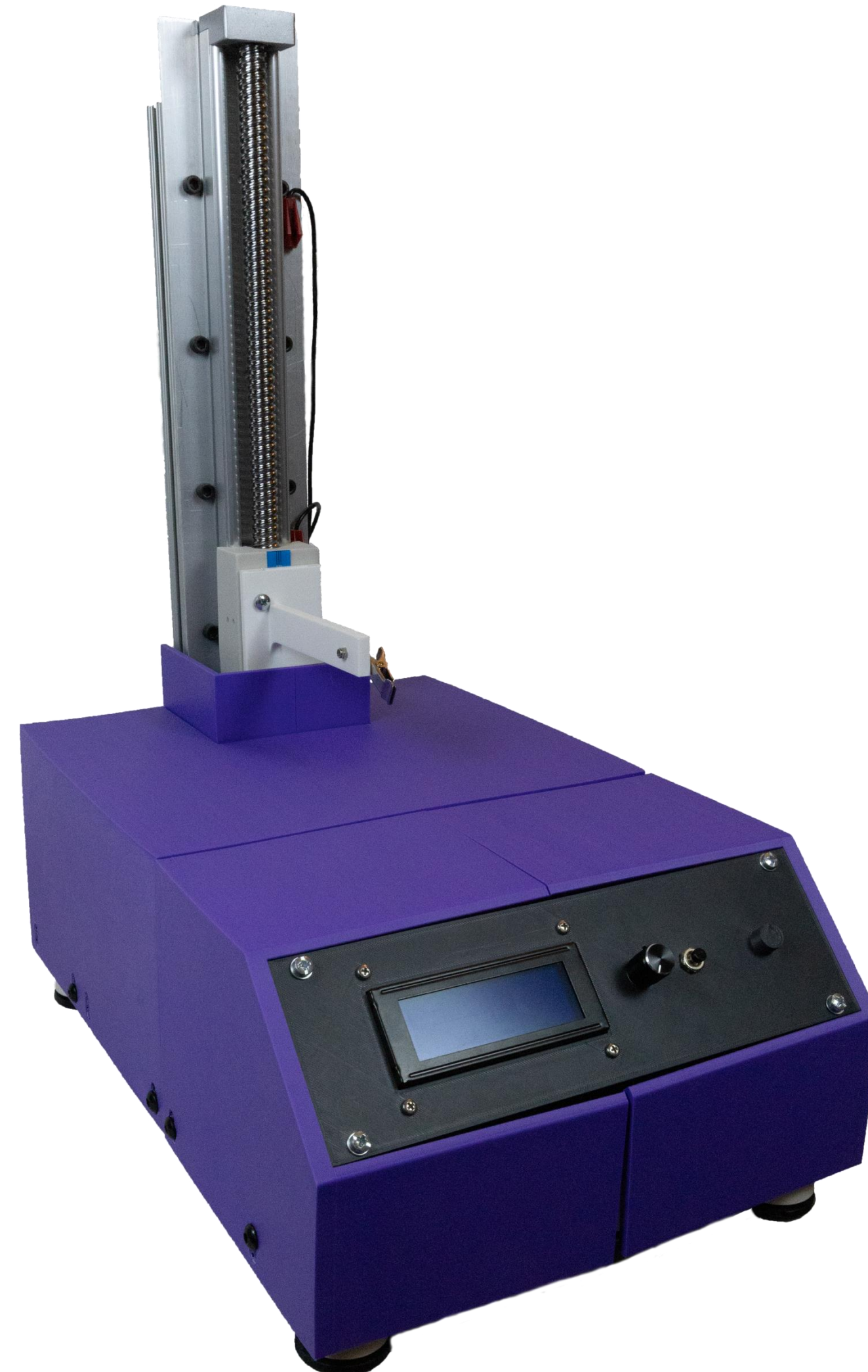


Figure 1. Completed Dip Coating Device Prototype

To meet the needs of the BNL, a two-phase project to design and prototype a dip and spin coating device was undertaken. Using commercial-off-the-shelf components (COTS), 3D printed casings, and basic machining operations, we have designed and assembled a prototype dip coating device for under \$350, as shown in Table 1. Furthermore, we were able to design and begin assembly of a prototype spin coating device for \$300, shown in Table 2, utilizing the same design method as the dip coating device.

The use of readily available motor sizing, Raspberry Pi Pico microcontrollers, and widely available LCD and user input components, the device can be easily serviced to repair non-functioning parts. Moreover, the modular design of both devices allows for future modification to add or enhance functionality.

Lastly, these devices are custom-built based on the wants and needs of the BNL. Feedback from the BNL was utilized throughout the design and prototyping phases to ensure the final prototypes meet their requirements. The final prototype dip coating device is shown in Figure 1. Testing of the dip coating device is shown in Figure 2. A rendering of the current prototype spin coating device is shown in Figure 3.

Table 1. Dip Coater Cost

Category	Cost
Electronics	\$120
Linear Actuator	\$140
Structure	\$80
Total	\$340

Table 2. Spin Coater Cost

Category	Cost
Electronics	\$120
Motor	\$100
Structure	\$80
Total	\$300

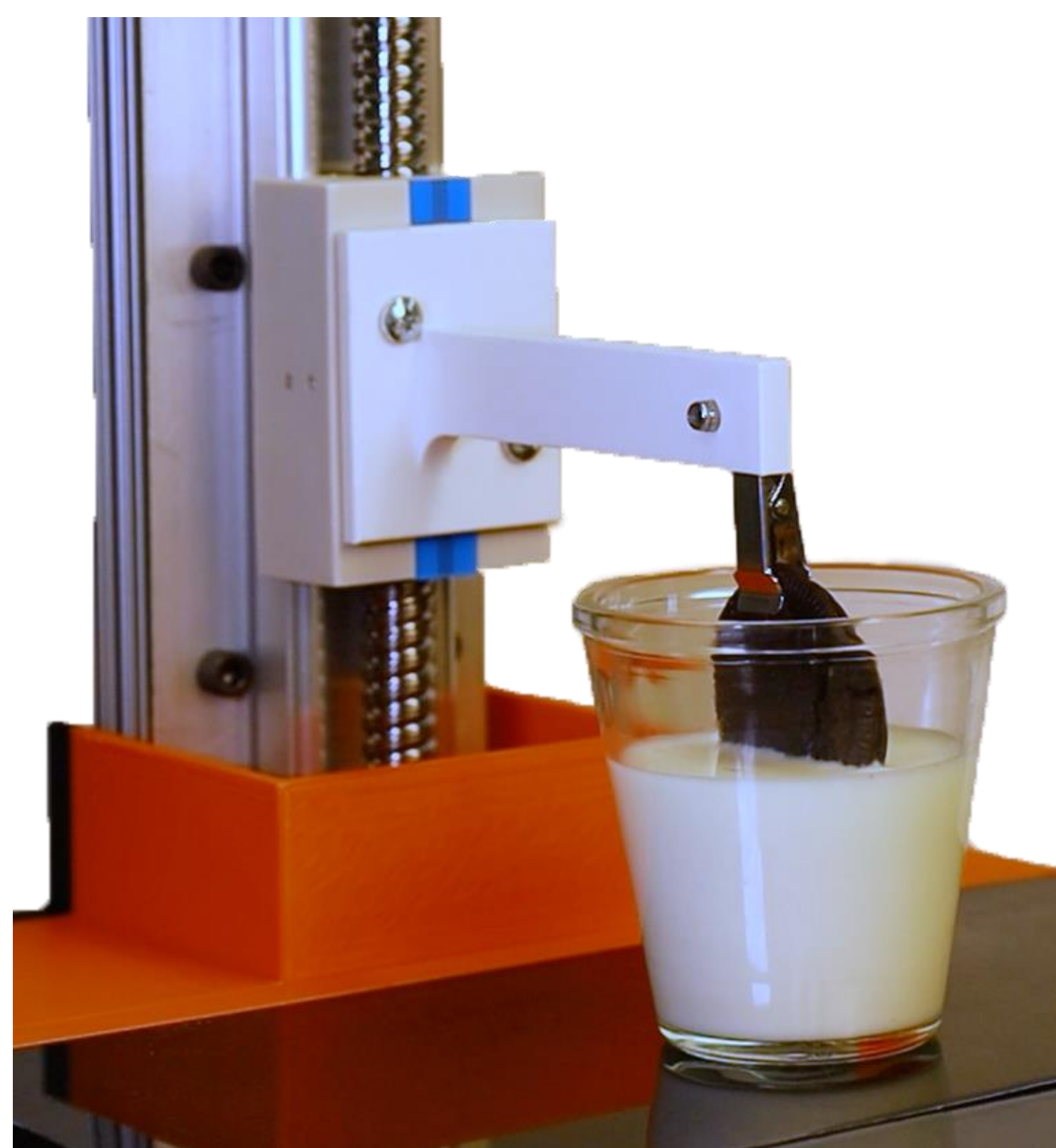


Figure 2. Testing of Dip Coating Device



Figure 3. Rendering of Spin Coating Device

Summary

Through the implementation of COTS components and low-cost structural materials, both devices were designed with components for a total cost of under \$500 for each device, making them accessible to research laboratories that may not have the funding or use to justify the expense to purchase commercially available systems costing several thousand dollars. The use of widely available and easily replaceable components also reduces the long-term maintenance costs and enables straightforward upgrades as newer, more efficient or better suited technologies become available. Finally, by designing these devices specifically for BNL, research in materials science, particularly work involving graphene coatings, can be conducted more efficiently and consistently than with manual coating methods, improving both throughput and experimental repeatability.

Contributions

Blake Cutler	Team Lead
	Structures
Joseph Emslie	Structures
Robert Jobe	Electronics
	Code
Phillip Nguyen	Electronics
	Code

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References

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2. UL. Combustion (Fire) Tests for Plastics. Website. Online; accessed 2025-12-03. url: <https://www.ul.com/services/combustion-fire-tests-plastics>.
3. Christy Dunlap et al. "Design and fabrication of a low-cost and programmable dip coating machine". In: HardwareX (2022).