Robotic Spray-Scanning for Uniform Transparent Conductive Films

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Abstract

Motivation: Solar energy is the most promising renewable energy source due to the vast amount of power emitted by the sun. As such, we need to be able to harness this energy on a scalable level. The conventional solar cell fabrication method is limited by energy costs, machine size, lack of scalability, and difficulty handling curved substrates. In order to address these issues, recent research efforts have focused on developing spray-castable solar cell technology using nanomaterials. This project involves the invention and development of a robotic scanning platform used to improve film uniformity and reduce clumping in transparent electrode materials for colloidal quantum dot solar cells.

Methods: The linear scanning motor is driven by a 12V power source and controlled by an Arduino Uno R3 via an interfacial stepper motor controller. The speed of the motor is tuned by a knob potentiometer, and feedback from an ultrasonic distance sensor facing the platform informs a PID control process. A liquid crystal display (LCD) presents the user interface, where buttons control the starting and stopping of motion as well as programmable functions. The platform itself was printed on a Formlabs Form 3 stereolithographic printer and designed using SolidWorks. The pieces are modular to allow for varying platform sizes.

Introduction

Current fabrication processes for solar cells require large amounts of input energy and typically require expensive capital resources. In most cases, machinery is not readily mobile so devices can only be made in a lab setting on flat substrates. Additionally, the maximum capacity of each tool limits the size of the final product.

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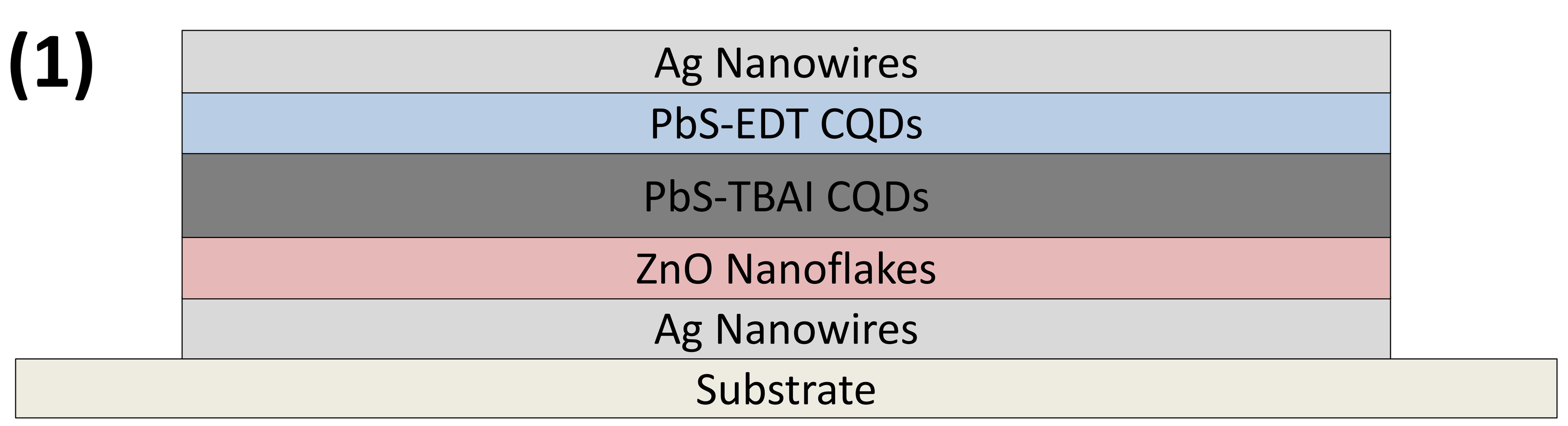
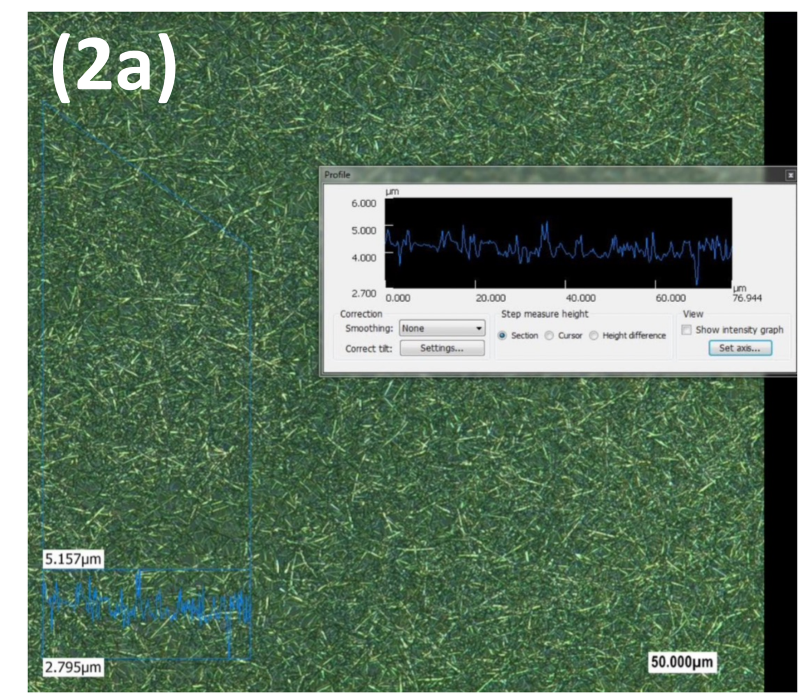


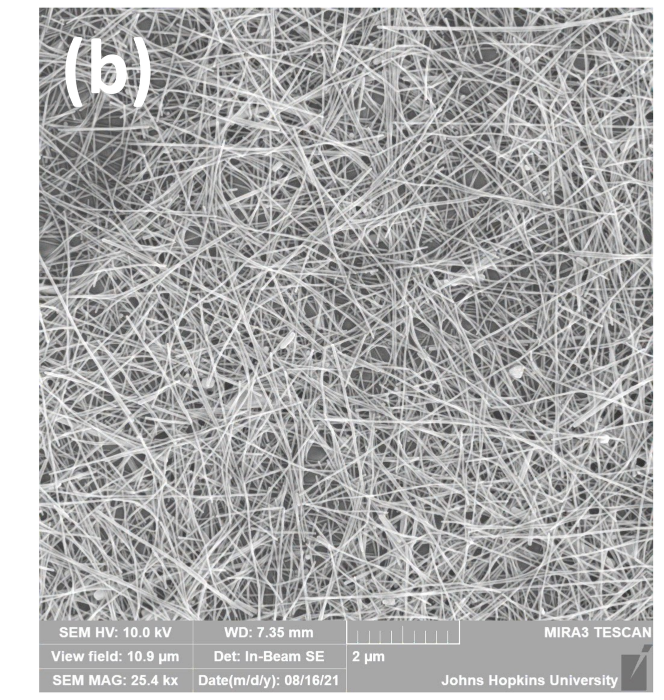
Over the past several decades, advancements in nanotechnology have allowed scientists to achieve previously unimaginable feats. In photovoltaics, devices made entirely out of nanomaterials as in figure **(1)** perform similarly to traditional first-generation cells. Since we can easily transport and cast these materials in liquid form, the door is open for scalable, on-site solar cell fabrication.

As of today, each layer has been successfully sprayed individually, yet not together to create a fully-functioning device. Particularly, poor film uniformity and droplet clumps in the transparent conductive layer cause significant limitations to a device's performance. This project details the invention and capabilities of a programmable robotic scanning platform for spray-casting colloidal quantum dot solar cell materials.

Silver Nanowire (Ag-NW) Films

Fig. 2) Images of silver nanowire (Ag-NW) transparent electrodes taken using **(a)** laser scanning microscopy (LSM) and **(b)** scanning electron microscopy (SEM). The blue line in (a) is mapped to its z-height profile in the inset. The Ag-NW morphology determines their performance as transparent electrodes in solar cells.





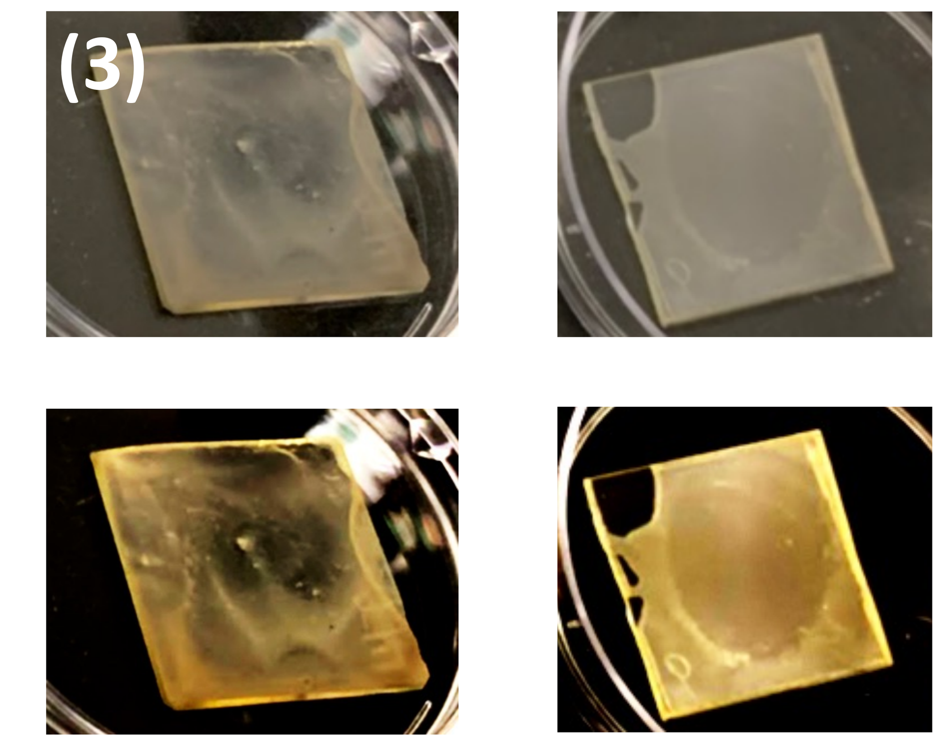
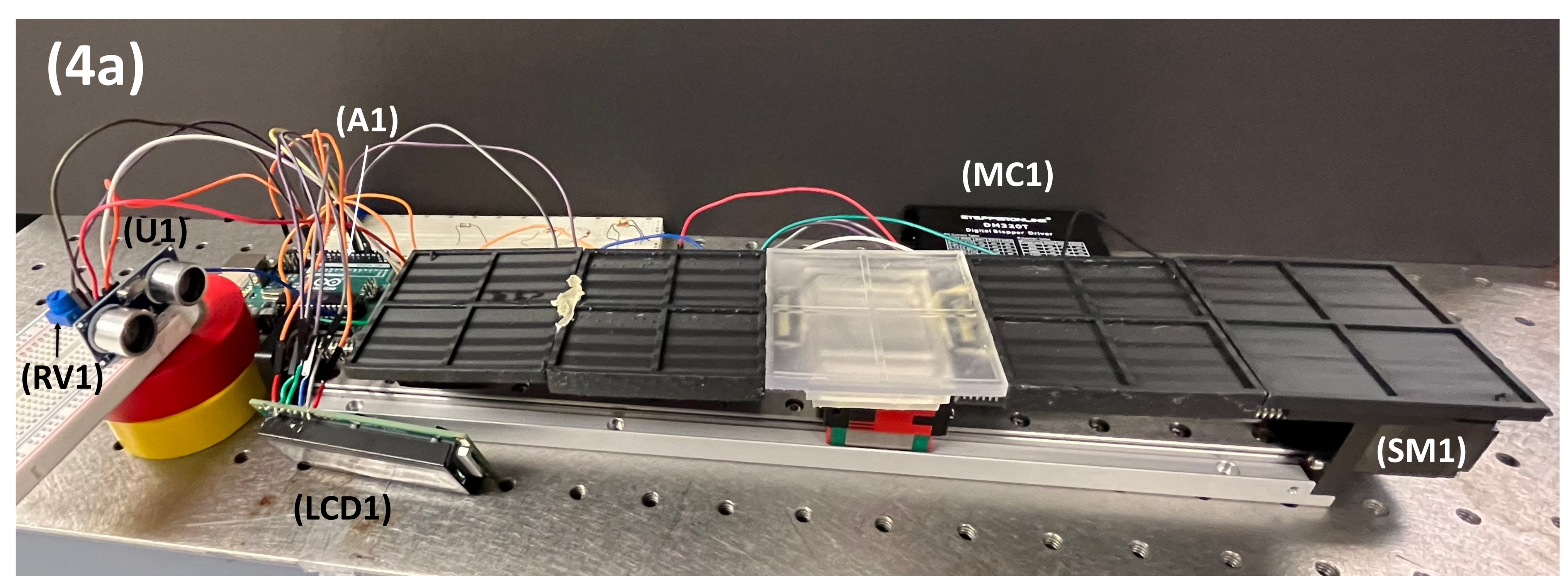


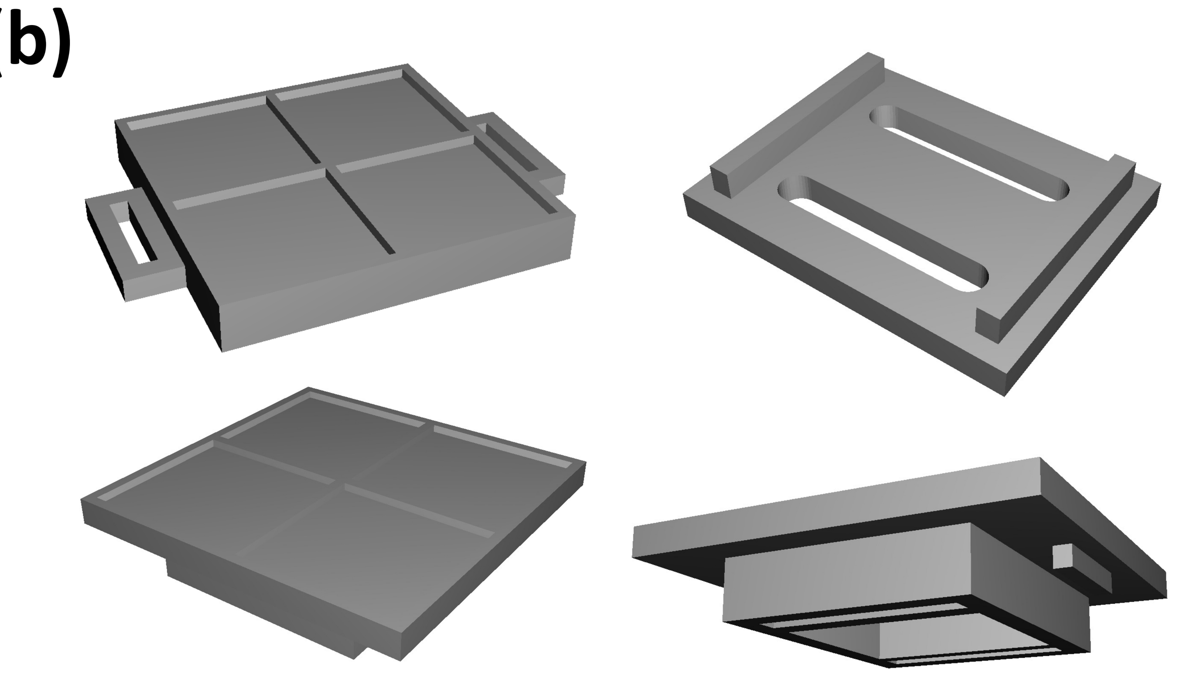
Fig. 3) Photographs of Ag-NWs spray cast onto glass substrates. The bottom row has increased contrast to highlight remaining inconsistencies in the films.

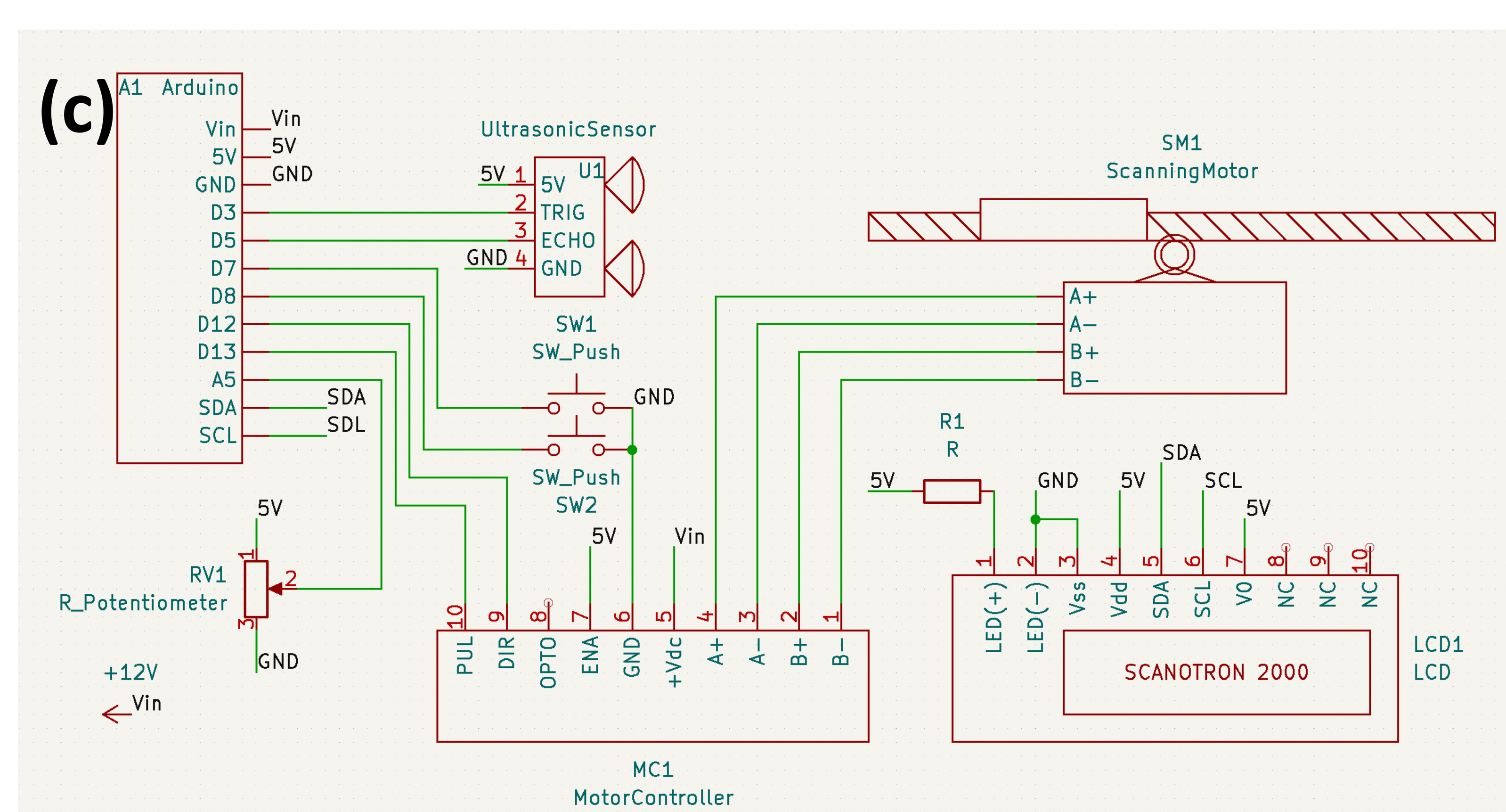
Robotic Scanning Platform Schematics and Prototype

Fig. 4) Experimental design and resulting device. The three-dimensional computer automated design (CAD) files appear in **(a)**. The top two models are the same, fitting into the bottom right part which attaches to the lateral scanning motor. The bottom left part acts as an interlocking piece to make a platform of arbitrary length. The first prototype appears in **(b)**, and its circuit schematic is drawn in **(c).**



(b)





Conclusions

The robotic scanning platform will allow us to exert more control over spray-casting conditions. We plan to optimize parameters such as platform speed, number of steps, and scan range in order to decrease surface roughness and increase film homogeneity. Additionally, we will examine the combined effects of this technology with other pre- and post-treatment processes such as substrate annealing, mechanical stamping, solvent washing, and droplet ultrasonication to produce high-quality transparent electrodes for solar cells.

Acknowledgments

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