Tyler Lewis Clean Energy Research Foundation
2020 Grant Recipients

Efficient Switches, Perovskite Photovoltaics and Organic Solar Cells

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*Three-Terminal Suspended Graphene Energy Efficient Switches

Replacing the Transistor

For many decades now, solid-state transistor technology has evolved rapidly to meet our requirements for faster and more efficient electronics. These transistors are used in digital circuits everywhere, however modern electronic hardware still contributes significantly to our global energy consumption; 21% of global electricity production is projected to be consumed by information technology in 2030.[1] Finding an alternative to conventional transistor technology is crucial in order to minimize the energy we consume, and electromechanical switches could fit the bill. They consist of ultrathin membranes that are actuated using an electric field. They can be designed to operate at lower voltages than conventional transistors, while retaining competitive operating speeds and relatively small sizes.

Suspended Graphene Switches

Graphene is a mono-atomic layer of carbon atoms, and is the strongest known material. Due to its extreme thinness, graphene is very flexible. Moreover, it has low mass resulting in the membrane springing back into place in nanoseconds once the electric field is turned off, resulting in an extremely fast and efficient switch.

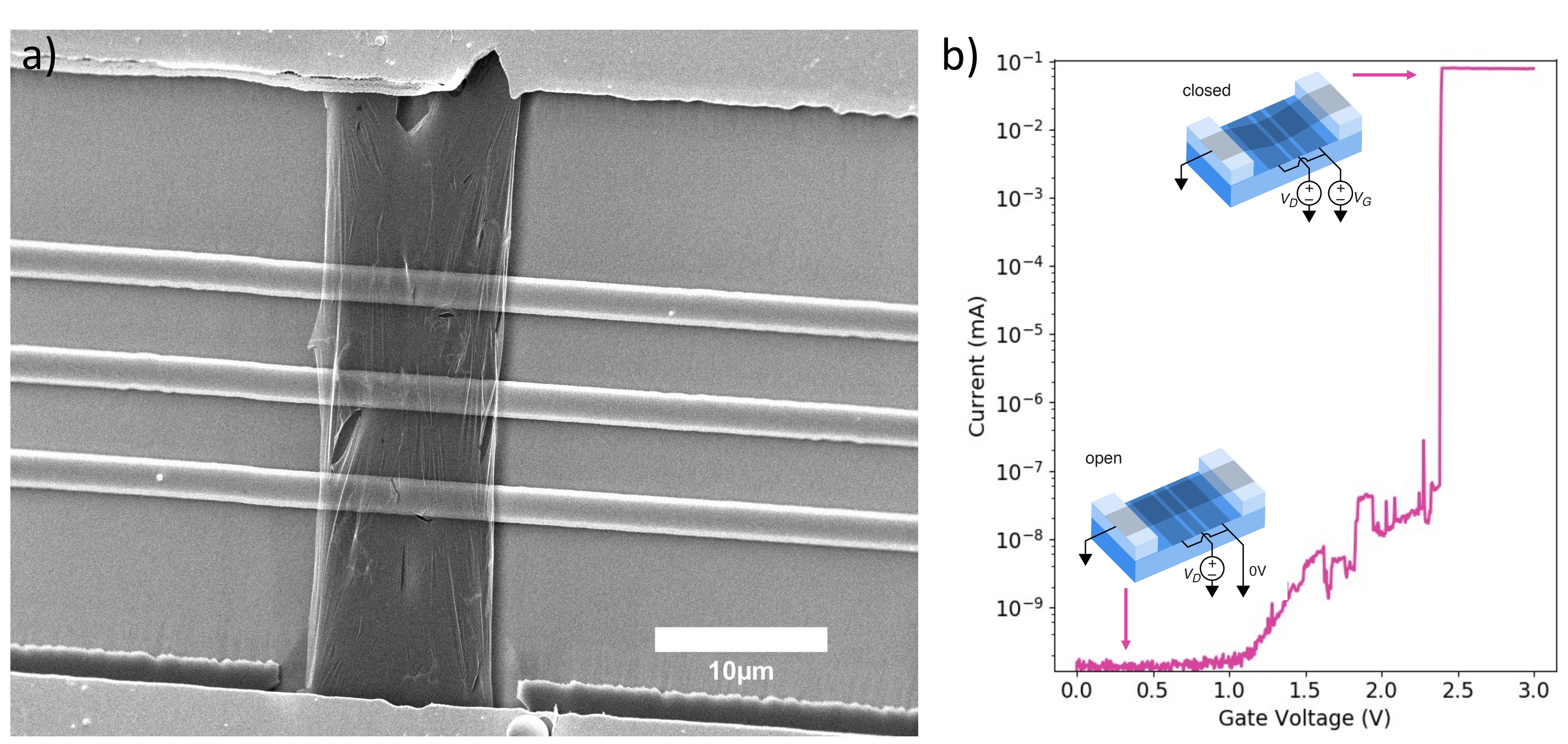


Figure 1: a) Scanning electron microscope (SEM) image of a suspended graphene switch device viewed from a 60° angle. b) Current-voltage measurement of a similar suspended graphene switch, where the open and closed states of the switch are illustrated at corresponding positions of the graph.

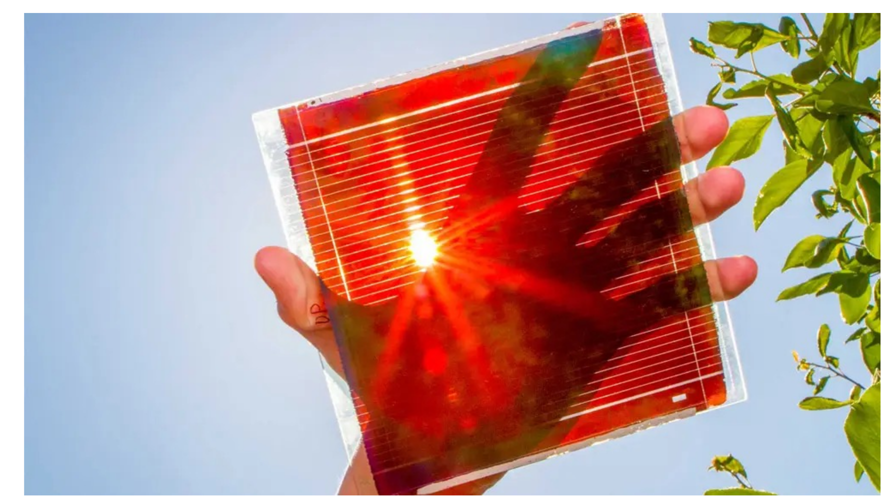
Our goal is to produce a three-terminal suspended graphene switch that can be operated well below 1V. Utilizing theoretical calculations and state-of-the-art fabrication methods will allow highly energy efficient switches that can be effortlessly integrated into simple logic circuits.[2]

1. N. Jones, Nature 561 (2018), 163-166
2. T. Szkopek, E. Martel, Prog. Quant. Elec. 76 (2020), 100315

†Semiconductor Perovskites for Solution-Processed Photovoltaic Devices

Perovskite photovoltaic devices

Lead halide perovskites have recently emerged as the most viable candidates to replace conventional solar cells, already reaching similar efficiency in a brief time. The key advantages of perovskites lies in their exceptional electrical properties combined with their low-cost manufacturing due to their low temperature processing and low materials cost.



Why are perovskite photovoltaic devices important?

The immense potential of solar energy is a proven alternative in the face of impending energy and environmental crises. Significant advances in photovoltaic devices such as prolonged lifetime and reduced cost must be achieved before they become a mainstay in the energy sector. Solution-processed materials like perovskites will address manufacturing and installation costs. Perovskites are capable of flexibility, and large and versatile surface coverage compatible with large-scale manufacturing.

Proposed Solution

Practical deployment of high efficiency perovskite-based photovoltaic devices is currently hindered due to use of lead as the metallic element as well as inherent instability resulting in rapid degradation. We will develop a newly emerging lead-free 2D perovskite structure. We will employ a state-of-the-art blade coating deposition technique to develop highly efficient Pb-free perovskite photovoltaic devices with prolonged lifetime.

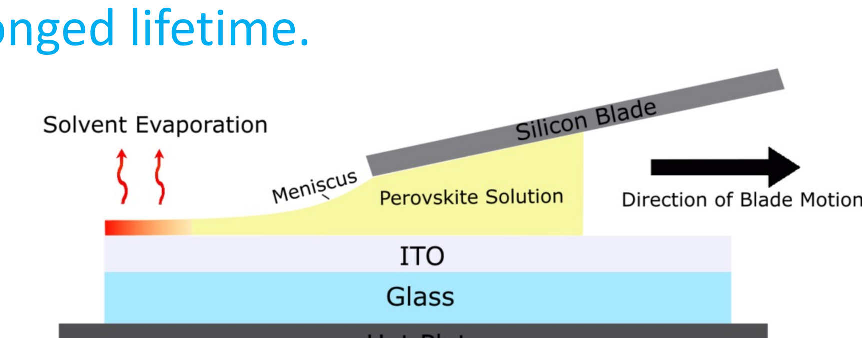


Figure: Blade Coating Deposition Technique

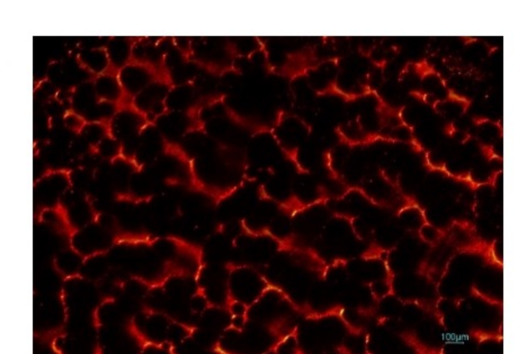


Figure: Perovskite Film of High Quality

‡Investigating Charge Transfer in Organic Solar Cells

Why Organic Solar Cells?

Organic (carbon-based) photovoltaic materials have the capability to fundamentally alter our engagement with solar energy: devices made of these materials can be thin, flexible, light-weight, semitransparent (transparent to visible light), low-cost, and take relatively little energy to produce. However, increases in efficiency are required before OPV devices can become a viable alternative to silicon-based solar cells.

Examples of Current and Near-Future OPV Applications

a.

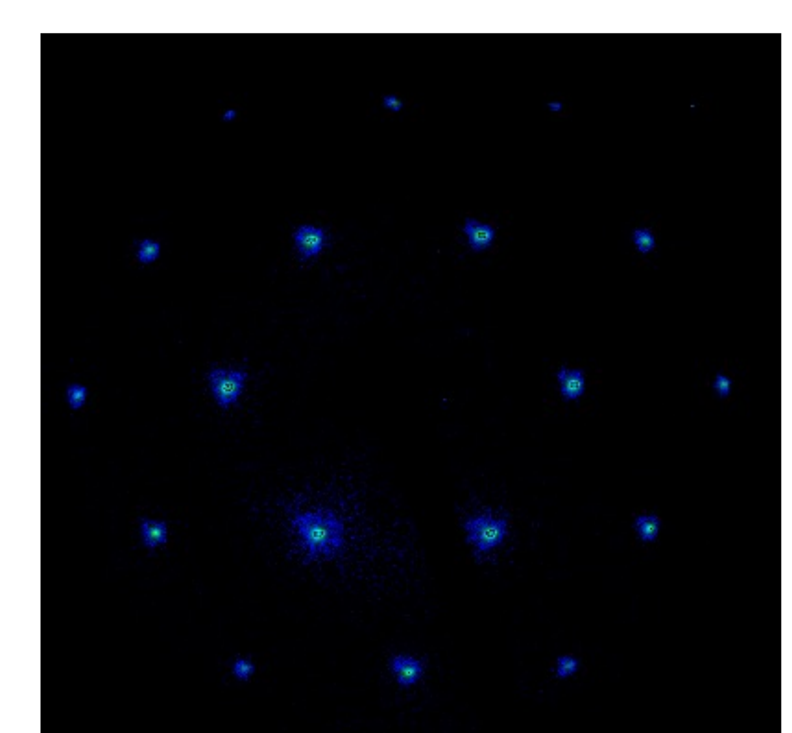
b.

c.

a. Window at EFPL's SwissTech Convention Center
b. Organic solar window at Michigan State University
c. The Mercedes-Benz G-code concept car

Primary Barriers and Our Approach

One of the principal causes of inefficiency is poor charge transfer, and we do not yet understand the physics that underlie it. In order to probe the physics of charge transfer in these materials, we use a combination of scanning tunneling microscopy and spectroscopy, as well as time- and angle-resolved photoemission spectroscopy. With these techniques, we can construct a map that details the spatial and temporal energy landscape of our organic films. This analysis requires extremely pure films, which we grow in-house in our organic molecular-beam epitaxy growth chamber.



Low-Energy Electron Diffraction is a surface characterization technique used to assess the caliber of our thin films. In this image, the distinct spots in a hexagonal pattern speaks to the quality of our organic thin-film.

Stewart Blusson Quantum Matter Institute