

# Planar Nanomaterials for Use as Electron-Blocking Layers in Organic Solar Cells

ISEN URG, Summer 2010

Throughout the summer, I experimented with boron nitride and graphene oxide as potential electron-blocking layers for use in organic photovoltaics. I researched in the Hersam research group under the guidance of Ian Murray. Published material in ACS Nano establishes that graphene oxide can be used as an electron-blocking layer in the context of organic photovoltaics. My work this summer has confirmed these results and further shown that graphene oxide offers significant advantages over a more commonly used electron-blocking material, PEDOT:PSS. My work with boron nitride has been to develop a technique suitable for the deposition of a layer several nanometers thick and to prove the currently theoretical usefulness of boron nitride as an electron-blocking layer.

In order to develop graphene oxide as an electron-blocking layer, I repeatedly fabricated solar devices in order to compare devices made with the PEDOT:PSS layer and devices made with the graphene oxide layer. These comparisons led to a greater understanding of what makes a good electron-blocking layer.

First of all, I helped to reproduce the results that were published earlier this year in ACS Nano, which first established that graphene oxide functions well as a PEDOT:PSS substitute. My experiments showed that while graphene oxide doesn't result in absolute device efficiencies as well as PEDOT:PSS, the efficiencies are comparable, thereby affirming that graphene oxide exhibits electron-blocking properties. Devices fabricated with graphene oxide between the anode and the active layer exhibit more current than devices fabricated without graphene oxide.

To take this result further, I pursued experiments designed to highlight graphene oxide's strengths as a robust, planar, nano-material. By studying the lifetime degradation of high-efficiency cells, it appears now that cells fabricated with a PEDOT:PSS layer degrade faster than those cells fabricated with a graphene oxide layer. The acidity of PEDOT:PSS makes it a poor choice for long-term device performance. In order to simulate the lifetime degradation of organic photovoltaic devices, the solar cells were heated for a given number of hours in a nitrogen environment and then tested. By tracking the change in efficiency, it now appears clear that although PEDOT:PSS results in an initially more efficient device, graphene oxide will result in a better device over its lifetime.

I also fabricated devices with the intent to show lifetime stability of organic solar cells when exposed to humidity. In order to do this, devices were fabricated without the encapsulation step, which would allow water in the air to reach the devices. In order to create working devices

without encapsulation, air-stable electrodes were deposited instead of the more common combination of lithium fluoride and aluminum. Although the humidity testing has not yet begun, devices were again fabricated using a relatively high-efficiency active layer known as PTB7:PCBM. Half of the devices contained a graphene oxide electron-blocking layer, while the other devices contained a PEDOT:PSS electron-blocking layer. Once the solar cell analyzer is repaired, this testing will begin.

I have also explored the use of boron nitride as an electron-blocking layer. Initial experiments showed that a layer of boron nitride between the anode and the active layer of organic photovoltaics creates a slight improvement in short circuit current compared to devices created without this layer. The cells fabricated with boron nitride are not yet comparable in efficiency to those fabricated with PEDOT:PSS as the electron-blocking layer. By examining the nature of these boron nitride films deposited, I hope to be able to improve the boron nitride deposition process and create a more uniform film of controllable thickness so that I can optimize device performance.

Ultraviolet-visible spectroscopy of boron nitride films suggested a correlation between deposition time and layer thickness, but the results were inconclusive due to several inconsistent depositions and the fact that layer thickness of the boron nitride has currently only been roughly estimated. Boron nitride film deposition has been indirectly verified by a change in surface roughness, observed with atomic force microscopy. Following the deposition of boron nitride films on several substrates, the surface roughness decreased, creating a more ideal surface on which to fabricate organic photovoltaics.

I certainly learned more than I can begin to recount this summer, and I am thankful for the wonderful experience afforded to me. I look forward to continuing my work in the Hersam research group and further exploring the many aspects of planar electron-blocking materials in organic photovoltaics.

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