The Future of Energy: Analyzing the Topography of Solar Cells

Amanda M. Parry [1,3] and Helen A. McNally[2,3]
Department of Physics[1],
Department of Electrical and Computer Engineering Technology[2],
Birck Nanotechnology Center[3],
Purdue University, West Lafayette, IN 47907

Efficiency is a major focus of solar cell research. Previous research has been conducted showing a connection between the topography of a solar cell and its efficiency using atomic force microscopy (AFM).[1] Researchers have investigated the effects different production processes have on efficiency as well as the efficiency involving different solutions of donor and acceptor layers of one type of solar panel.[2] This paper focuses on the use of AFM to characterize the topography of both crystalline and organic solar cells. A connection between a solar cell's surface area and efficiency is investigated.

A Solarex polycrystalline panel was used for the crystalline sample. This module consists of 36 separate polycrystalline silicon solar cells connected to make the solar panel.[3] The polycrystalline solar modules are a collection of cells cut from a cast square ingot of silicon. This technology is less efficient than a monocrystalline solar panel, which is cut from a single cylindrical ingot.[4] In comparison, an organic solar cell is made of a conductive polymer that makes use of organic electronics. Organic electronics are carbon-based unlike the silicon used in the crystalline solar cells.[5] Although organic panels are cheaper to produce than the silicon alternative, polycrystalline panels have a higher efficiency when converting sunlight into usable energy. The highest module efficiency of a polycrystalline panel is 14.74 % (Kyocera Solar) compared to the 8.81% (Solyndra) module efficiency of the most efficient organic solar cell on the market.[6]

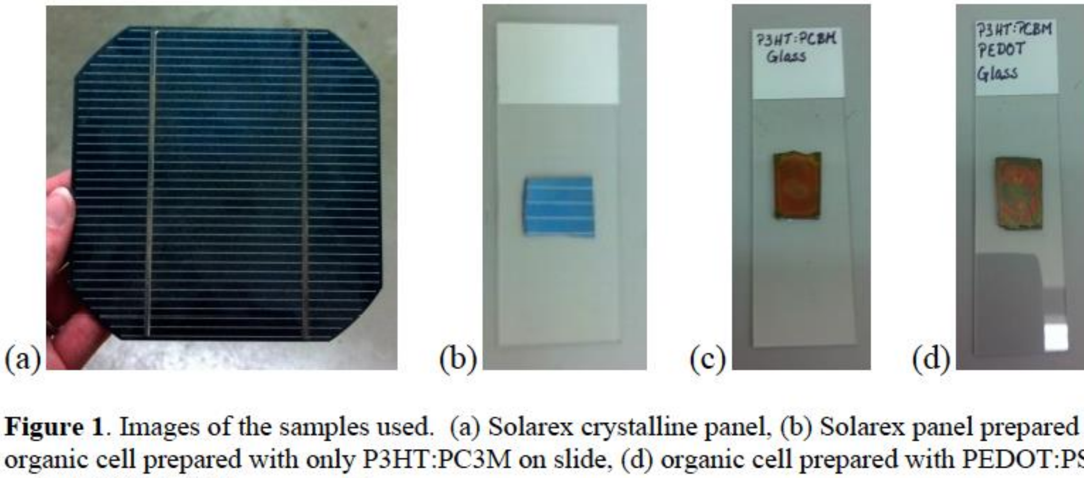

Figure 1. Images of the samples used. (a) Solarex crystalline panel, (b) Solarex panel prepared on slide, (c) organic cell prepared with only P3HT:PC3M on slide, (d) organic cell prepared with PEDOT:PSS layer under P3HT:PC3M layer on slide

Figure 1 shows the types of solar panels used in this research. A commercially available Solarex panel (model type MSX-5) was used for the crystalline sample. The panel (Figure 1, a) was taken out of the module and sliced with a razor blade. It was then cracked along the ridges made with the razor blade and attached to the glass slide with super glue (Figure 1, b). Aditya Baradwaj, a graduate research assistant at Purdue University's School of Chemical Engineering prepared two organic solar cell samples for this experiment. The organic cells were prepared on ITO coated glass substrates purchased from Thin Film Devices, Inc. The substrates were cleaned using ten-minute sonication cycles in acetone, chloroform, and isopropyl alcohol sequentially. The substrates were then blown dry with compressed nitrogen and then exposed to ozone plasma for ten minutes. On one of the substrates, two layers of PEDOT:PSS were applied to the ITO glass surface using spin-coating. Inside a glovebox, a 50 mg/mL solution of P3HT: PCBM was applied on top of the PEDOT:PSS using spin-coating (Figure 1, d). On the other substrate, only the P3HT: PCBM solution was applied using spin-coating (Figure 1, c).[7]

The surface topologies of the samples were imaged using the Bioscope Catalyst (Bruker, Santa Barbara, CA) in dynamic mode with an OTESPA tip (Bruker Probes, Camarillo, CA). In this procedure, a tip on the bottom of an oscillating cantilever scans over the surface of the solar panel. The oscillation of the cantilever is altered as the tip interacts with the surface. These changes are detected by a laser, which is reflected off the cantilever and into a photo detector.[8] The detector records the position of the cantilever and provides feedback to the Z position of the scanner, which is adjusted to maintain a constant oscillation. This data is used to produce the images of the surface topography. Measurements of depth, width and surface roughness of features were taken to calculate the surface area available to collect energy on each panel.

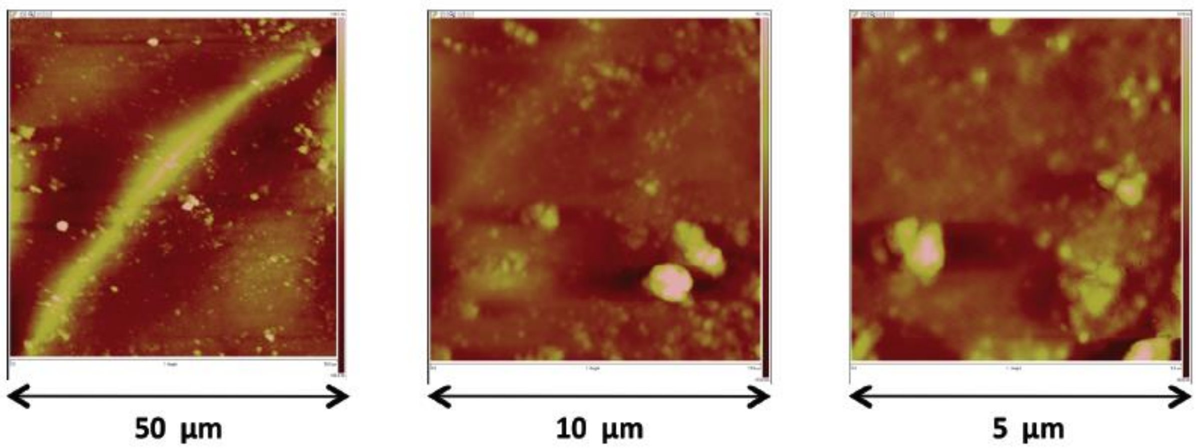

Figure 2. Images produced using AFM of the Solarex crystalline panel.

Figure 2 shows images of the Solarex crystalline panel at a 50 µm scale, a 10 µm scale, and a 5 µm scale. Figure 3 shows a cross section of the 10 µm square scan. A conglomerate in this image measures a width of 1.5 µm and a height of 300 nm.

The images in Figure 4 show a 50 µm square scan, a 10 µm square scan, and a 5 µm square scan of the organic panel with P3HT: PCBM directly on top of the glass substrate. Figure 5 shows a cross section of the 10 μm square scan. The cross section shows a conglomerate with a width of 2.5 μm and a height of 3 nm.

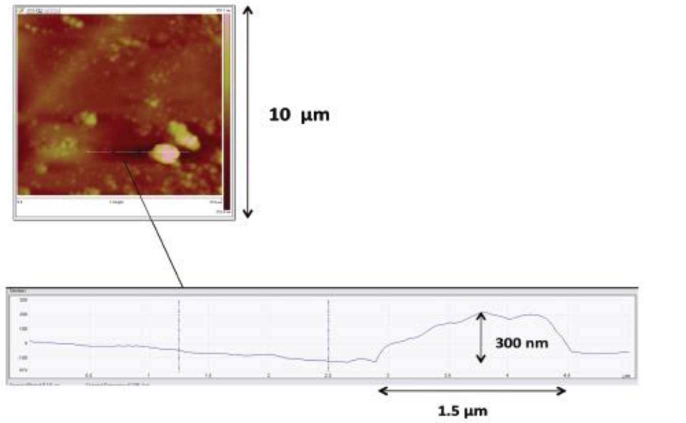

Figure 3. Cross section of 10 μm scale image of the crystalline panel.

The images in Figure 6 show a 50 μm square scan, a 10 μm square scan, and a 5 μm square scan of the organic panel with P3HT: PCBM on top of PEDOT:PSS, which is directly on top of the glass surface. Figure 7 shows a cross section of the 10 μm square scan. The conglomerates visible in the images of the organic panel without the PEDOT:PSS are no longer present. The cross section shows a projection from the surface with a width of 1 μm and a height of 8 nm.

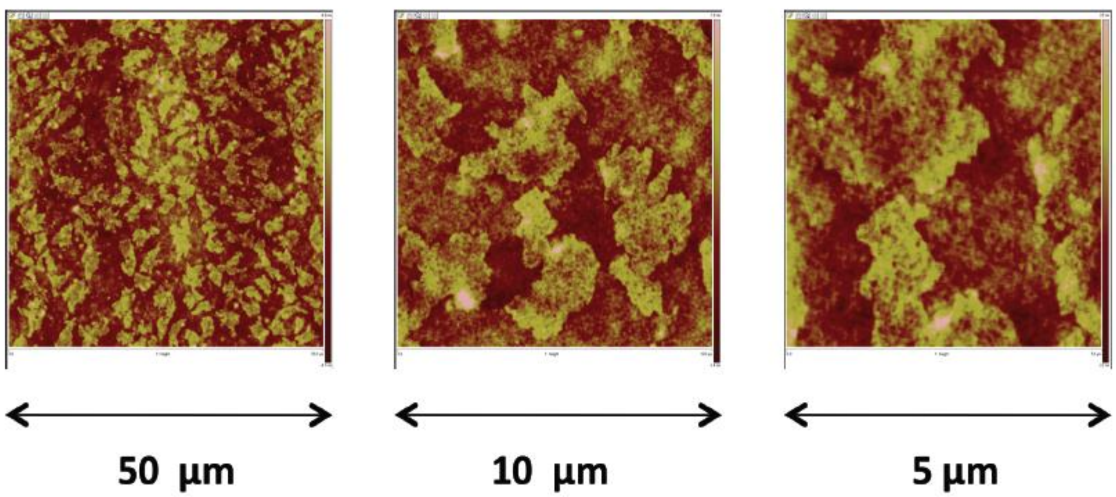

Figure 4. Images produced using AFM of the organic panel with only the P3HT:PCBM layer on the ITO glass slide.

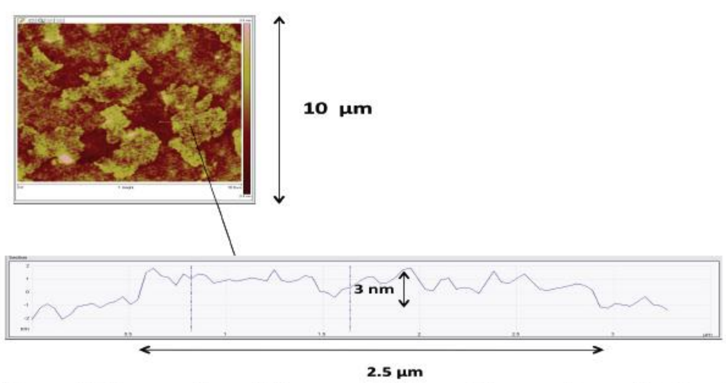

Figure 5. Cross section of 10 μm scale image of the organic panel with only the P3HT:PCBM layer.

Using these data sets, the surface area of each panel was calculated using the roughness analysis command of the Nanoscope software. This feature reports the surface area of the flat image, the surface area of the projected image, and it also compares the difference between the two surface areas.[9]

The surface area difference

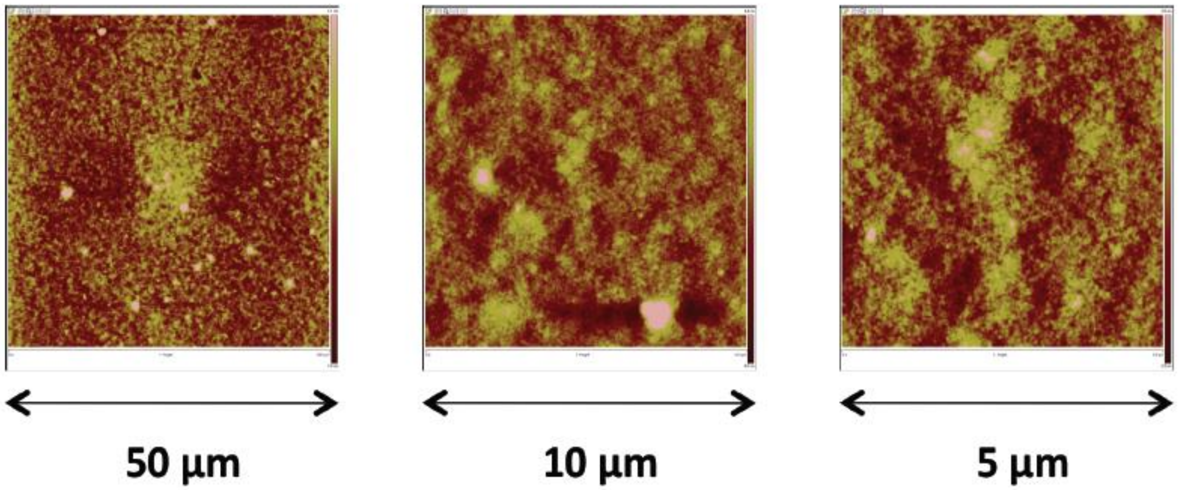

Figure 6. Images produced using AFM of the organic panel with the P3HT:PCBM layer on top of the PEDOT:PSS layer.

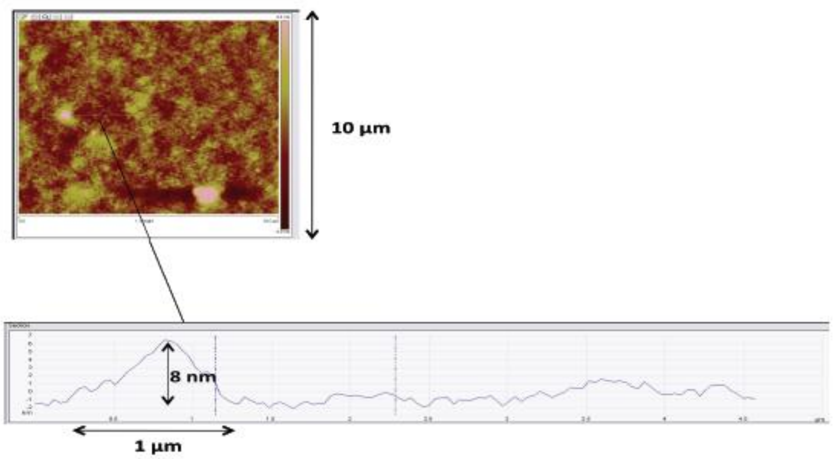

Figure 7. Cross section of 10 µm scale image of the organic panel with the P3HT:PCBM layer on top of the PEDOT:PSS layer.

displayed in Table 1 is the difference between the analyzed region's projected surface area and its two-dimensional area. Calculations were made for the 50 µm square scans of each panel. The polycrystalline panel has more available surface area than both forms of the organic panel. The organic P3HT: PCBM panel without PEDOT:PSS has a slightly larger surface area difference than the organic panel with PEDOT:PSS.

Table 1

Panel	**Surface Area Difference**
Polycrystalline	0.201 %
P3HT: PCBM	0.00204 %
P3HT: PCBM with PEDOT	0.0018 %

The percent differences in surface area correlate to the general efficiencies for both types of panels of about 5% for organic panels and about 15% for crystalline panels. In order to understand the overall effect topography has on the energy efficiency of solar cells, additional experimentation is required. This should include various types of solar cells as well as looking at the process of solar cell development.

Acknowledgments: Thank you to A. Baradwaj and P.R.I.M.E. lab for providing samples.

1. Soga, T., (2006). *Nanostructured materials for solar energy conversion*. Amsterdam: Elsevier.
2. van Duren, J.K.J., Yang, X., Loos, J., Bulle-Lieuwma, C.W.T., Sieval, A.B., Hummelen, J.C., & Janssen, R.A.J. (2004). Relating the morphology of poly(p-phenylene vinylene)/ methanofullerene blends to solar-cell performance. *Advanced Functional Materials*, 14(5), 425-434. doi: 10.1002/adfm.200305049
3. *MSX-5 and MSX-10 photovoltaic modules* (datasheet). Retrieved from http://www.datasheetarchive.com/MSX-5-datasheet.html
4. Corona Solar: Solar technologies decoded. Retrieved from http://www.coronasolargroup.com/corona_solar_006.htm
5. (2013). Organic solar cell. Retrieved from http://en.wikipedia.org/wiki/Organic_solar_cell
6. (2012, May 19). Most efficient solar panels. Retrieved from http://sroeco.com/solar/most-efficient-solar-panels
7. Baradwaj, A., (personal communication). January 6, 2013.
8. Veeco Instruments, Inc. (2010). *Bioscope Catalyst User Guide*, Theory of AFM operation, Tapping mode AFM, 27-28
9. Veeco Instruments, Inc. (2008). *Nanoscope software 6.3 user guide* (Revision A).

The author, Amanda Kollak, is from Cedar Lake, Indiana. She studied physics as an undergraduate at Purdue University and minored in mathematics and political science. In her final semester, she conducted this research with Professor McNally through the Discovery Park Undergraduate Research Internship (DURI) program. While at Purdue, she worked as a student operator at P.R.I.M.E. lab and participated in the Women in Physics program. Amanda currently lives in Meridian, Mississippi and can be reached at akollak6@gmail.com.