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Photovoltaic Materials and Fiber Based Photovoltaics

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We have fabricated photovoltaic devices directly onto fiber optics as a novel photovoltaic device. In this presentation, we demonstrate that by using optical fibers to “waveguide” the light into the polymer photovoltaic device, significant performance enhancements can be achieved through enhanced light gathering. The typical shortcomings of planar devices, such as loss to radiative recombination, and poor optical performance of the thin absorbing films, are addressed in this architecture by greatly extending the optical path length within the absorber of the device and confining the radiation modes of the fiber. Not only does this result in enhanced collection of light normally incident on the devices, but it also provides for increased light gathering at oblique incident angles. This leads to the astonishing result that the power generation of fiber-devices, over the course of the day, can be nearly double that of a planar device of the same efficiency rating! Importantly, this work shows that materials properties typically responsible for loss within planar devices act to enhance the fiber photovoltaic response.

In this presentation we present a detailed experimental characterization together with a mathematical model for fiber-based geometries in organic photovoltaics. Our model consists of two parts: computing the optical path and then the respective energy loss for each path. Through this model, the processes involved in light transmission, absorption and loss, have been simulated for different incident angles and positions on the face, for different fiber lengths, and for different fiber diameters. In this model we show that light incident along the middle line of the fiber is most strongly absorbed by the P3HT absorber and falls off for incident position along the periphery if the fiber. We show experimentally that the predicted relationship between efficiency and incident angle compares well for a given fiber length. Further, we show that there is an optimum length in terms of other parameters of the fiber cell. Finally, we show that experimental results on efficiency versus fiber diameter are well reproduced by our simulation for reasonable fiber diameters. However, for small diameter fibers, we show a direct proportion between the absorption and the diameter. Finally, the results discussed above are for individual fibers. We can now show the performance from large areas of aligned fibers acting as a single solar cell correlate strongly with the results from individual fibers. We have fabricated devices of several square centimeters that exhibit the angular response and high current densities suggested by our models and by our preliminary single fiber data.