Aluminum-doped Zinc Oxide Transparent Conductors for Optical Cavity Enhanced Polymer Photovoltaics

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Introduction
Photovoltaics are very important to the future energy industry as a reliable source of clean, renewable energy. Though inorganic photovoltaics are the standard option, organic devices offer several advantages. Due to their easier processing, they can be economically manufactured on substrates that are both lightweight and flexible. However, they are not yet as efficient as inorganic photovoltaics. In an effort to increase their efficiency, we are investigating optical cavity effects to increase photon absorption in the active layer, here the organic polymer layer, of the devices. This project focuses on studies of organic photovoltaic devices using Aluminum-doped Zinc Oxide (AZO) as the transparent electrode. AZO shows promise as an emerging abundant, low-cost and environmentally friendly transparent conductor.

Objectives
- Sputter deposit the AZO on glass slides
- Measure complex index of refraction using spectroscopic ellipsometry
- Films should be transparent and conductive
- Calculate transfer matrix model of the device and its absorption spectra
- Design, construct, and characterize devices using I-V curves and external quantum efficiency

Methods
AZO was sputter deposited on clean glass microscope slides at two thicknesses: 300 nm and 600 nm. The 300 nm films were not conductive enough to suffice as an electrode; their bulk resistivity was measured to be between 60 and 150 Ω/square in a pure N₂ environment after 2 to 3 consecutive anneals at 350°C. To function as an electrode, the resistivity should be in the 10s of Ω/square. The 600 nm films, however, were within this range, with a resistivity between 35 and 50 Ω/square even after a week of degradation in air. Spectroscopic ellipsometry was performed on the samples to determine their complex index of refraction. The AZO layer was modeled as a standard Lorentz oscillator to model the interband absorption with an added Drude component to model the free carrier absorption. The resulting index of refraction data was used to carry out calculations simplified using transfer matrices.

The device is constructed of a glass substrate; the transparent conducting oxide, here AZO; an electron blocking layer, PEDOT:PSS; the active layer consisting of P3HT and PCBM; and finally a top electrode of Aluminum. Future Work
The next step is to fabricate devices based on the results from the transfer matrix calculations. These plots will then be compared to current devices.

Results
The absorption for devices modeled by the transfer matrix was plotted as previously demonstrated. These figures were produced for devices consisting of a 1mm glass substrate; AZO; 40 nm of PEDOT:PSS, the electron blocking layer; 0-400 nm of PCBM/P3HT, as plotted; and 100 nm Al. The AZO thickness was plotted at 500 to 800 nm in steps of 50 nm, as more precise thicknesses are difficult to fabricate.

Conclusions
The highest absorption is expected for thinner devices, here, as the thinnest modeled device, 500 nm AZO and around 200 to 250 nm for the PCBM/P3HT layer, which should absorb 55 - 75% of the incoming light. Though the trend toward higher absorption with thinner AZO layers would suggest that the optimum absorption is lower than 500 nm, commercial AZO is not conductive enough to serve as an electrode at thicknesses much thinner than this. This is in comparison to previously studied devices using 150 nm of Indium Tin Oxide (ITO) as their transparent conducting oxide, with all other device details being the same, which demonstrated 80 - 100% absorption at the most absorptive active layer thicknesses.

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Reference
1 A.C. Galca et al., Thin Solid Films 518, 4603 (2010).