Enhanced Performance in Quantum Dot Solar Cell with TiO$_x$ and N$_2$ Doped TiO$_x$ Interlayers

Jialin Yu
Advisor: G.E. Jabbour, T.L. Alford

Abstract

As the 3rd generation solar cell, quantum dot solar cells are expected to outperform the first 2 generations with higher efficiency and lower manufacture cost. Currently the main problems for QD cells are low conversion efficiency and stability. This work is trying to improve the reliability and the device performance by inserting an interlayer between the metal cathode and the active layer. Titanium oxide and a novel nitrogen doped titanium oxide were compared and TiO$_x$N$_y$ capped device shown a superior performance and stability to TiO$_x$ capped one. A unique light anneal effect on the interfacial layer was discovered first time and proved to be the trigger of the enhancement of both device reliability and efficiency. The efficiency was improved by 300% and the device can retain 73.1% of the efficiency with TiO$_x$N$_y$ when normal device completely failed after kept for long time. Photoluminescence indicted an increased charge disassociation rate at TiO$_x$N$_y$ interface. External quantum efficiency measurement also inferred a significant performance enhancement in TiO$_x$N$_y$ capped device, which resulted in a higher photocurrent. X-ray photoelectron spectrometry was performed to explain the impact of light doping on optical band gap. Atomic force microscopy illustrated the effect of light anneal on quantum dot polymer surface. The particle size is increased and the surface composition is changed after irradiation. The mechanism for performance improvement via a TiO$_x$ based interlayer was discussed based on a trap filling model.

Then Tunneling AFM was performed to further confirm the reliability of interlayer capped organic photovoltaic devices. As a powerful tool based on SPM technique, tunneling AFM was able to explain the reason for low efficiency in non-capped inverted organic photovoltaic devices. The local injection properties as well as the correspondent topography were compared in organic solar cells with or without TiO$_x$ interlayer. The current-voltage characteristics were also tested at a single interested point. A severe short-circuit was discovered in non capped devices and a slight reverse bias leakage current was also revealed in TiO$_x$ capped device though tunneling AFM results. The failure reason for low stability in normal devices was also discussed comparing to capped devices.