Interdigitated Electrodes for Organic Solar Cells

CNF Project # 775-99
Principal Investigator: George G. Malliaras
Users: Yee-Fun Lim, John DeFranco

Affiliation: Materials Science and Engineering, Cornell University
Primary source of research funding: Agency of Science, Technology and Research (A*STAR), Singapore
Contact: ggm1@cornell.edu, yl325@cornell.edu, jad93@cornell.edu

Abstract

A new device structure is proposed for organic solar cells, whereby multiple organic semiconducting layers are deposited in between inter-digitated electrodes. It aims to have the multiple advantages of efficient light absorption, and charge carrier generation and collection. Inter-digitated electrodes have been fabricated using a wet-etch undercut method as well as a two-step lithography process. The first yielded small electrode gaps of ~ 200 nm between rough electrodes, while the second produced a gap of ~ 450 nm with much smoother electrodes.

Summary

Organic solar cells have attracted much attention in recent years due to their significant cost advantages and ease of processing and fabrication as compared to their inorganic counterparts (such as silicon cells). A major drawback of organic solar cells is their low efficiency, and a lot of work has gone into getting better efficiencies from these cells.

To achieve high efficiency, it is necessary to incorporate a heterojunction, which is an interface between a donor and an acceptor organic semiconductor material. Excitons created by photon absorption in either material diffuse to the heterojunction, which are then dissociated into electrons and holes due to the offset in the highest occupied molecular orbital/lowest unoccupied molecular orbital (HOMO-LUMO) levels of the two materials. Good light absorption, efficient exciton dissociation and charge carrier collection are all important for a highly efficient cell. The two most common device structures are the bilayer heterojunction and the bulk heterojunction, neither of which boasts all three of the above mentioned properties.

We propose a new “planar” device structure that incorporates all the above features. Such a structure consist of interdigitated electrodes of two metals with different work functions, with multiple donor and acceptor organic semiconducting layers deposited in between. Figure 1 shows a schematic of the cross section of such a device. Individual layers can be made as thin as necessary to facilitate exciton diffusion, while multiple layers can be deposited to increase light absorption. Finally, the charge collection will be driven by the electric field arising from the difference in metal work functions, and the carriers will have a connected pathway to the electrodes.

Two different methods have been employed to fabricate the interdigitated electrodes. In the first method, the first metal is patterned by lithography and dry etching (ion milling), followed by a wet etch undercut step. The second metal is then deposited, and unwanted metal is removed by liftoff.
This process is good for producing very narrow gaps (~200 nm), but the electrodes have very rough edges (Figure 2). The second method is simply a two-step lithography process whereby the two electrodes are patterned one after the other by liftoff. Much smoother electrodes are obtained (Figure 3), although the gap is significantly larger (~450 nm). Future work will involve the deposition of organic layers in between the electrodes, as well as solar cell testing and characterization.