To my family: Your love and dedication made this possible

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ABSTRACT

NANOSTRUCTURED ORGANIC SOLAR CELLS: TOWARD HIGH EFFICIENCY, LARGE SCALE AND VERSATILITY

by

Hui Joon Park

Chair: L. Jay Guo

This dissertation is devoted to searching for solutions to realize low-cost, high efficiency and scalable organic solar cells (OSC), and their versatile application. For this purpose, my research has been focused on various nanostructures, which can be usable to maximize the performances of OSCs, and the effective fabrication processes to achieve those nanostructures. Furthermore novel device concepts based on those nanostructures have been introduced.

First part of dissertation is about controlling the nanostructures in photoactive layers to develop more efficient OSC devices. A new process, named as ESSENCIAL, inducing superior bulk heterojunction (BHJ) morphology was developed. Compared with conventional annealing based-methods, the optimized BHJ morphology showing well-organized charge transporting pathways with high crystallinity was achieved. Moreover, by controlling the interface of the photoactive layer, further improvement of power

conversion efficiency (PCE) was possible using BHJ structure. A new type of heterojunction nanostructure based on bilayer concept was also introduced. By maximizing interdiffusion of electron-donor and -acceptor, the optimized heterojunction morphology having internal quantum efficiency approaching about 100% was demonstrated. As another effort to realize the ideal interdigitated donor-acceptor structures, sub-20 nm scale nanopillars were prepared. Nanopillar and nanohole type nanoimprint lithography (NIL) molds were fabricated from a self-assembled block copolymer nanotemplate, and NIL-based nanopatterns are made in organic semiconductor. All these nanostructures could be realized by advanced processing that can be extended to high-speed manufacturing toward low-cost and high efficiency OSCs.

Secondly, various nanostructures such as plasmonic nanostructures and light trapping structures were developed to enhance the absorption of light in OSC devices. NIL-based plasmonic nanostructures exhibit strong and tunable light extinction, and the enhanced electromagnetic field induces the increased photocurrent, leading to improved PCE. Moreover, by introducing periodic nanostructure at the metal electrode working as reflector in OSC, I could enhance the optical path length across a broad wavelength range of incident light.

Lastly, the dual-function devices working as color filters and solar cells were demonstrated by applying photonic nanostructures to OSCs. This new conceptual device can recycle the wasted energy in color filter to generate the electricity for the revolutionary energy-saving e-media.