

To my family: Your love and dedication made this possible

ACKNOWLEDGMENTS

It is a great pleasure to thank those who made this thesis possible. First and foremost, I would like to show my gratitude to my advisor, Prof. L. Jay Guo, who has supported me throughout Ph. D study with his patience, encouragement and guidance. Without his supports, this thesis would not have been possible, and I cannot thank him enough for what he has done for me in the past five years. I am also highly thankful to my committee members, Prof. Peter F. Green, Prof. Jinsang Kim, and Prof. Zhaohui Zhong for their valuable suggestions throughout this study.

I would like to acknowledge all current and past nanogroup members, Dr. Carlos, Dr. Dawen, Dr. Haofei, Dr. Hongseok, Dr. Jing, Dr. Li-Jing, Dr. Moon Kyu, Dr. Myung-Gyu, Dr. Phillip, Dr. Se Hyun, Dr. Sung-Liang, Dr. Ting, Dr. Yi-Hao, Abram, Alex, Ashwin, Brandon, Cheng, Christina, Hyoung Won, Hyunsoo, Jae Yong, Jong, Kyeongwoon, Kyu Tae, Long, Peng, Tao, Xiaodong, Yi-Kuei, Young Jae for their kindness and help for my study. I would also like to acknowledge the staff and student members of Lurie Nanofabrication Facility, Solid State Laboratory and Electron Microbeam Analysis Laboratory for their kind help during my study. It was a great luck for me to work with wonderful facility and people. My special thanks go to Korean Macro, MSE, ChemE and EECS people for their help in my living at Ann Arbor.

I am greatly indebted to my parents for their love and supports throughout my life. I also wish to thank my wife, Jiwon for her love and sacrifice; and my beloved sons, Jaewoo. Without my family's love and dedication, this thesis would not have been

possible.

Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of Ph. D study.

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ABSTRACT

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

by

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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.