

Abstract

Organic photovoltaic devices have evinced interest due to the prospects of integrating strongly absorbing semiconducting polymers in flexible, light weight device platforms with ease of fabrication. However, there are significant performance issues to be addressed in these devices which include issues at the pixel level and those at the panel level. In this thesis, we address design and fabrication issues in the context of two distinct problems – that of enhancing optoelectronic performance at the pixel level using nanostructured platforms, and that of identifying and modelling catastrophic failure mechanisms in these devices.

A major part of the thesis deals with the enhancement of optoelectronic performance using a nanostructured photovoltaic architecture. Based on design insights from optical transport studies on a photovoltaic architecture with Nano-pillars, an optimized nanostructured platform is designed and fabricated for optoelectronic enhancement. A two-step template based melding process to obtain nanostructured substrates based on novel mouldable transparent materials, on which we demonstrate broadband light trapping. We show that this design brings about dual advantages – firstly an enhancement in the absorption through trapped surface plasmon modes at the absorber-electrode interface and bulk guided modes in the active layer, and secondly an improved charge separation due to enhanced built in fields. Subsequently the problem of material optimization is considered where the combined effects of the nanostructured geometry and the optoelectronic properties of the absorber layer are studied using simulations.

In the remainder of the thesis, problems relating to identification, characterization, and modelling of catastrophic failure in device are addressed. Coupled electro-thermal processes are shown to be at the root of structural damage, which results in two distinct types of structural defects in the device. We develop an analytical model to evaluate the failure criteria, which shows excellent agreement with the experimentally observed defects. Using these models, one could design robust devices for large panels, where thermally initiated issues pose a challenge.