Abstract

Increasing energy demand and diminishing non-renewable energy resources have resulted in facing our biggest challenges for the last decades, and these are indications for more alarming problems such as global warming and pollution. The motivation for this research is based on the state-of-the-art actions to take in order to solve these problems and propose that eco-friendly organic photovoltaics can play a vital role.

The most abundant and clean energy is solar, and it needs to be utilized with cost-effective and eco-friendlier techniques in the future. Existing solar panels that are commonly used are fabricated in a costlier manner and they require materials that can negatively impact the environment. Whereas, organic photovoltaics (OPV) offer both lightweight architecture and eco-friendliness, and their efficiencies are approaching to 20% with ongoing research which are exceptionally promising.

Yet, the most important challenges for OPVs are their large-scale applicability and environmental effect for future industrial production. In order to fabricate large-scale and also flexible devices, it is preferrable to be able to experiment with materials that are processable in air without using toxic chemicals in a cost-effective way.

Therefore, this thesis focuses on both optimization of photo-active layers of OPVs with non-halogenated processing solvents and fabrication of these eco-friendlier solar cells via slot-die coating printing technique. The donor-acceptor (D-A) groups of organic materials are selected initially to be evaluated in inverted devices and different post-treatments were methodically analysed. The successful solvent systems that gave the best performing devices for polymer-fullerene and polymer-non fullerene D-A pairs were specifically tested and characterized for their applicability in printed devices.

In Chapter 3, a highly popular donor polymer PTB7-Th and non-fullerene acceptor (NFA) ITIC pair was tested in devices made using eco-friendly solvent systems with spin-coating process. The existing solvent systems and fabrication ways for the formation of the organic thin film layer for the same polymer and fullerene systems were also used for comparison. The best performing device efficiency with NFA system was found to be greater than that of reported in the literature and our experiments gave a PCE of 8.5% even when we use our eco-friendly fabrication method.

Also, techniques for efficient and proper removal of toxic solvent additives for the same D-A pairs were investigated. In order to support this research besides the device performances, surface and thermal characterizations were further carried out.

In Chapter 4, the motivation was solely on the eco-friendly fabrication and optimization of photo-active layers of solar cells. High performing devices using less harmful solvent systems were found for PTNT polymer and fullerene materials, and they are tested later in Chapter 5 for their applicability for printing techniques.

In Chapter 5, materials that were extensively studied in previous chapters were also evaluated for flexible device fabrication with eco-friendly methods and post-treatments such as PTNT polymer and fullerene acceptors. PTNT polymer gave high efficiencies (~5%) with this flexible device processing using green solvents, and supported our proposal of new fabrication techniques and use of non-halogenated solvent systems in many more OSC materials commonly tested in literature. The device photovoltaic properties and the microscopy images of the thin film layers were always reported to complement each other and supported our arguments when different treatments were applied. The morphology controllability using pre-and post- treatments of active layers were investigated in detail, especially in Chapter 3 and 5.

In summary, the inverted polymer solar cells were fabricated with novel green and cost-effective techniques and examined for other comparable polymer-acceptor systems for the best efficiency and eco-friendliness. They were also tested in flexible cell architecture appropriateness and proved their importance for future use in large-scale green solar cell applications with good efficiencies.

Keywords: polymer solar cells, eco-friendly, solvent additive, OSC, NFA, non-fullerene acceptor, slot-die coating, mini-roll coater, printed solar cell, spin-coating, environmentally friendly, annealing, vacuum drying.