Abstract

Organic photovoltaics represent the third generation PV technology, and it is a technology that offers large cost reductions using inexpensive materials and low cost printing fabrication techniques such as roll-to-roll processing. The lower power conversion efficiencies of organic solar cells, however, limit their viability and sustainability for cost competitive commercial production. Plasmonic assisted organic photovoltaics have a potential to increase the performance of devices and thus reduce the cost/kW of generating capacity. This is the motivation of the work presented in this doctoral thesis.

Metallic nanostructures are used to enhance the light absorption within the semiconductor film in organic solar cells. A new lithography-free method for nanostructure formation from conjugated polymer is presented in this work. A highly concentrated polyethyleneglycol-capped gold nanoparticles suspension from ethanol is drop casted on corrugated silicon-based organic polymer stamps for arranging the nanoparticles. Surface-ordered gold nanoparticle arrangements are hereafter integrated at the bottom electrode of organic solar cells. The resulting optical interference and absorption effects are experimentally and numerically investigated in bulk hetero-junction solar cells. In addition, the light absorption effects are numerically investigated as a function of size and periodicity of the plasmonic arrangements. Our study reveals the light harvesting ability of template-assisted nanoparticle assemblies in organic solar cells.

Although the integration of light-trapping features and exploitation of metal nanostructure plasmonic effects are promising approaches for enhancing the power conversion efficiency of organic solar cells, one has to also consider nanostructure-induced electrical effects on the device performance. In this work, we exemplarily model the electrical properties of organic solar cells with rectangular-grating structures, as compared to planar reference devices. Based on our numeric results, we demonstrate that, beyond an optical absorption enhancement, the device fill factor improves significantly by introducing the grating structures. From the simulations we conclude that enhanced carrier collection efficiency is the main reason for the increased solar cell fill factor. This work contributes towards a more

fundamental understanding of the effect of nanostructured electrodes on the electrical properties of organic solar cells.

Finally, we investigate the effect of periodic gold nano-triangle arrays on the performance of the organic solar cells. We fabricate the large-area gold nano-triangle arrays on ITO substrate using nanosphere lithography. The device with periodic gold nanostructures exhibits a broadband light absorption enhancement. In this work, the correlation between light absorption enhancements and enhanced device performance is investigated.

Together with the prospect of low production cost and the ease of scalability, we believe that the presented nanostructures in this thesis will have the potential to increase the efficiency of the solar cells and hold prospect to be beneficial in various optical and optoelectronic devices.

Resumé

Organiske solceller repræsenterer tredje generation solcelleteknologi som er en teknologi der tilbyder store omkostningsreduktioner ved brug af mere priseffektive materialer samt print fabrikationsteknikker såsom rulle-til-rulle processering. Den lave effektivitet for organiske solceller har dog begrænset deres anvendelse og bæredygtighed til konkurrencedygtig kommercielt produktion. Plasmon assisterede organiske solceller har et potentiale til at øge ydeevnen af devices og dermed reducere pris/kW af den genereret kapacitet. Dette er motivationen for arbejdet præsenteret i denne PhD afhandling.

Metalliske nanostrukturer bruges til at forstærke lysabsorptionen i halvledende film anvendt i organiske solceller. En ny litografi-fri metode til formation af nanostrukturer fra konjugerede polymerer er præsenteret i dette arbejde. En meget koncentreret polyethyleneglycol-dækket nanopartikel opløsning dråbe-påføres korrugerede Silicium baserede organiske polymer stempler for at arrangere nanopartiklerne. Overfladearrangeret guld nanopartikler integreres herefter på bundelektroder i organiske solceller. Den resulterende optiske interferens og absorptionseffekt er undersøgt både eksperimentelt og numerisk i 'Bulk-heterojunction' solceller. Ydermere er lysabsorptionseffekterne numerisk undersøgt som funktion af størrelsen og periodiciteten af plasmon arrangementerne. Vores studier fremviser de template assisterede nanopartikel arrangementers egenskaber til at høste lys i organiske solceller.

Selvom integrationen af lysindfangende egenskaber og udnyttelsen af metal nanostruktur plasmon effekter er lovende tiltag for at forøge effektiviteten af organiske solceller er det også nødvendigt at indregne nanostruktur inducerede elektriske påvirkninger af device ydeevnen. I dette arbejde modellerer vi eksemplarisk de elektriske egenskaber af organiske solceller med rektangulære gitter strukturer, og sammenligner disse med standard reference devices. Baseret på vores numeriske resultater demonstrerer vi, at der udover en optisk forøgelse ligeledes er en forøgelse af device 'fill factor' ved introduktion af gitter strukturerne. Fra vores simulering kan vi konkludere at en forøgelse af ladningssamlings effektiviteten er baggrunden for den forøgede 'fill factor' i solcellerne. Dette arbejde bidrager til en mere fundamental forståelse af effekterne fra nanostrukturerede elektroder på de elektriske egenskaber af organiske solceller.

Endeligt undersøges effekten af periodiske guld nano-trekant rækker på ydeevnen af organiske solceller. Vi fabrikerer guld nano-trekanter rækker på stor skala ovenpå ITO substrater vha. nano-kugle litografi. Devices med periodiske guld nanostrukturer udviser en bredbånds lysabsorptionforøgelse. I dette arbejde er korrelationen mellem lysabsorptionsforøgelser og forbedret device ydeevne undersøgt.

Sammen med mulighed for lave produktionsomkostninger og opskalering mener vi at de i denne afhandling præsenterede nanostukturer har potentialet til at forøge effektiviteten af organiske solceller, samt ydermere at tilbyde anvendelsesfordele i forskellige optiske og optoelektroniske deivces.