Organic Solar Cells with Efficiency of ∼9% Achieved by Using Multiple Plasmonic Nanostructures

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Abstract— Polymer-fullerene-based bulk heterojunction (BHJ) solar cells have many advantages including low-cost, low-temperature fabrication, semi-transparency, and mechanical flexibility [1, 2]. However, there is a mismatch between optical absorption length and charge transport scale [3, 4]. These factors lead to recombination losses, higher series resistances and lower fill factors. Attempts to optimize both the optical and electrical properties of the photoactive layer in organic solar cells (OSCs) inevitably result in a demand to develop a device architecture that can enable efficient optical absorption in films thinner than optical absorption length [5, 6]. Here, we report the use of multiple metallic nanostructures to achieve the broad light absorption enhancement, increased short-circuit circuit (J_{sc}) and improved fill factor (FF) simultaneously based on a new small-bandgap polymer donor of poly {[4,8-bis-(2-ethyl-hexyl-thiophene-5-yl)-benzo[1,2-b:4,5-b']dithiophene-2,6-diyl]-alt-[2-(2-ethyl-hexanoyl)-thieno[3,4-b]thiophen-4,6-diyl]} (PBDTT-T-C-T) in BHJ cells [7]. The multiple metallic nanostructure consists of 2D arrays of metallic nanograting electrode as a back reflector and metallic nanoparticles (NPs) with different geometries embedded into the active layer. Apart from the waveguide modes and diffractions, we simultaneously introduce hybridized surface plasmonic resonances (from Ag nanograting) and localized plasmonic resonances (from Au and Ag NPs [8]) to successfully achieve a broadband absorption enhancement. The detail understanding has been described with our theoretically studies. Consequently, we improve PCE to ∼9% [9] by improving both optical and electrical properties of single-junction OSCs through introducing dual plasmonic nanostructures which contribute to the practical application of OSCs for photovoltaics.

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