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Plasmonic effects of gold nanoparticles on the performance of organic photovoltaic devices

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Extracting energy from sun light is one of the most promising ways to solve today's energy crisis. Direct conversion of sun energy to electrical energy using nanostructured organic/inorganic hybrid structures has attracted much attention for many years. In particular, plasmonics researchers are turning their attention to incorporation of metal nanoparticles (NPs) into the active layer of polymer solar cells (PSCs), where design approaches based localized plasmonic resonance effect (LSPR) can be used to enhance the optical absorption in photovoltaic devices, enabling a considerable reduction in the physical thickness of solar photovoltaic absorber layers. The localized surface plasmon resonance (LSPR) occurs in illuminated metallic nanoparticles, like gold nanoparticles (Au-NPs), when oscillations of the incident electric field resonate with the surface electronic charges on those nanoparticles. The strong LSPR near field mainly distributes laterally along the active layer, therefore, the metallic NPs can experimentally and theoretically enhance the light absorption in the active layer of PSCs. In this study, to enhance the power conversion efficiency (PCE) of the polymer solar cells (PSCs), Gold (Au) nanoparticles are incorporated into P3HT/PCBM active layers. Addition of Au NPs increased the power conversion efficiency by up to 43.9% compared to a reference cell without Au-NPs. The short circuit current(J_{sc}) of the cells containing 0.05 mg of Au NPs was measured at 7.509 mA/cm^2 compared to 5.558 mA/cm^2 in the reference cells without nanoparticles; meanwhile, the external quantum efficiency(EQE) increased from 61% to 65.5%, showing an enhancement of 7.37%. Au-NPs improved the charge collection at the anode, which results in higher short circuit current and fill factor.

Keywords: Plasmonic effect, UV-visible spectroscopy, PSCs, Au nanoparticles