RPAL: A Novel Low-Cost High-Efficiency Photovoltaic System Using Tunable Plasmonic Nanostructures

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In this integrative research, two tunable plasmonic nanostructures were used to significantly increase the short circuit current output (Jsc), total current produced (A), maximum optical generation rate (Gmax) in a novel organic solar cell (OSC), and the concentration factor in a novel luminescent solar concentrator (LSC). The first nanostructure is a raspberry-like metamolecule (RMM), an isotropic, gold-nanoparticles/polystyrene-core colloidosome, hypothesized to significantly improve the OSC due to its unusually strong magnetic resonance and broadband absorption spectra, changed by altering the size and packing density of the gold nanobeads. The second nanostructure is a gold nanorod (AuNR), dispersed in a glass medium, hypothesized to significantly improve the LSC due to its tunable extinction cross section peak (by changing its aspect ratio). Both particles are inexpensive to synthesize and utilize. 5 different sizes of RMMs were simulated. A finite-difference time-domain discretization technique with nonuniform boundary conditions was used for optoelectronic analysis simulations. The OSC component of the RPAL (RMM-Photovoltaic and AuNR-LSC system) was fabricated using a novel, hybrid method combining an induced Marangoni effect to uniformly disperse RMMs and spin coating to apply active P3HT:PCBM and base layers. Optical properties were determined using ellipsometry, atomic-force and dark-field microscopy. Extinction, absorption, and scattering cross sections, as well as Jsc, A, and Gmax, were analyzed. A 56.31% improvement of Jsc in the RPAL over a control OSC with a similar morphology without RMMs was observed, as well as a 31.13% improvement in a RPAL with a Si-based active layer over Si-based cells, proving the immediate utility to current and photovoltaics.

Awards Won:
Intel ISEF Best of Category Award of $5,000
First Award of $5,000
Office of Naval Research on behalf of the United States Navy and Marine Corps: The Chief of Naval Research Scholarship Award of $10,000
Qatar Foundation, Research &amp
Development: Award of $1,000
IEEE Foundation: The IEEE Foundation Presidents' Scholarship Award of $10,000