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Photoelectrochemical characterization of lead-based hybrid perovskite semiconductors

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A variety of PbI2/MAPbI3 perovskites were prepared and investigated by a rapid screening technique utilizing a modified scanning electrochemical microscope (SECM) in order to determine how excess PbI2 affects its photoelectrochemical (PEC) properties. An optimum ratio of 2.5% PbI2/MAPbI3 was found to enhance photocurrent over pristine MAPbI3 on a spot array electrode under irradiation. With bulk films of various PbI2/MAPbI3 composites prepared by a spin-coating technique of mixed precursors and a one-step annealing process, the 2.5% PbI2/MAPbI3 produced an increases photocurrent density compared to pristine MAPbI3 for 2mM benzoquinone (BQ) reduction at – 0.4 V vs Fc/Fc+. As a result of the relatively high quantum yield of MAPbI3, a time-resolved photoluminescence quenching experiment could be applied to determine electron-hole diffusion coefficients and diffusion lengths of PbI2/MAPbI3 composites, respectively. The diffusion coefficients combined with the exciton lifetime of the pristine 2.5% PbI2/MAPbI3 (τ_{PL} = 103.3 ns) give the electron and hole exciton diffusion lengths, ~ 300 nm. Thus, the 2.5% PbI2/MAPbI3 led to an approximately 3.0-fold increase in the diffusion length compared to a previous report of ~ 100 nm for the pristine MAPbI3 perovskite. We then demonstrated that the efficiency of liquid-junction solar cells for 2.5% excess PbI2 of p-MAPbI3 was improved from 6.0% to 7.3%.

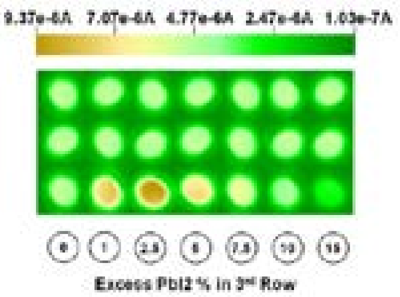

Figure 1. SECM images for a typical photocurrent response of PbI_2/$MAPbI_3$ composites under irradiation. The color represents the measured photocurrent shown in the scale bar above the SECM image. The first and second seven-spot rows are pure MAPbI3 perovskites. The third seven-spot row represents the amount of excess PbI_2 in each spot in the array electrode. The photocurrent shown is for 2 mM BQ reduction with 0.1M $TBAPF_6$ supporting electrolytes in CH_2Cl_2 measured at an applied potential of −0.4 V vs Fc/Fc+.

Biography

Sam H. Y. Hsu's research interests involve the material design, synthesis, processing, imaging, spectroscopy and solar energy application, aiming to explore fundamental properties and interactions of hybrid perovskite semiconductors and functional metallopolymer materials for developing efficient solar energy conversion processes. He has keen interests in photoinduced charge transfer processes, interfacial electron transfer, electrochemical hydrogen generation, and photoredox reactions for photovoltaics and solar fuel production. The investigations between material phenomena rely heavily on concepts and techniques of material and physical engineering, consisting of photophysics, electrochemistry, photoelectrochemistry, scanning photoelectrochemical microscopy imaging, ultrafast transient absorption and time-resolved photoluminescence spectra.

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