17a-S10-7

Enhancement of organic/hybrid solar cell performance via photoluminescence downconversion of surface-engineered silicon nanocrystals

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An alternative approach to take advantage of room temperature luminescent silicon nanocrystals (Si-ncs) is to integrate them as optical down-converters in solar cells. In particular, the degradation of organic solar cell devices is attributed to the absorption of high energy (UV) photons (> 3 eV) that considerably deteriorates the conjugated polymers. The use of highly photoluminescent Si-ncs represents an attractive option for UV photon management, whereby Si-ncs would absorb high energy photons, that is otherwise damaging the polymer-based active layer, and convert high energy photons into lower energy ones via room temperature PL. It is clear that the control of surface properties of Si-ncs at quantum confinement size remains one of the most important aspects for the integration of Si-ncs in solar cell structures. Controlling “mix” between the polymer matrix and the Si-ncs, is critical. In recent years we have demonstrated that surfactant free atmospheric pressure microplasma surface engineering of Si-ncs can be used as an efficient tool to control mixing and electronic interaction of Si-ncs with various type of polymers.

In this contribution we report on the optical and opto-electronic contribution of surface-engineered Si-ncs in organic and hybrid solar cell devices as photoluminescence downshifter. We demonstrate that a water-soluble hybrid nanocomposite formed by surface-engineered Si-ncs embedded in poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) can be used to enhance the efficiency of organic/hybrid solar cells via downshift and increasing of the photocurrent generation. In particular we have used the Si-ncs/PEDOT:PSS nanocomposite as optical converter for polythieno[3,4-b]thiophenebenzodithiophene (PTB7):[6,6]-phenyl-C71-butyric acid ([70]PCBM) bulk heterojunction solar cells. Surface-engineered Si-ncs can be integrated in the device architecture to be optically active and provide a mean of effective down-conversion for blue photons (high energy photons below ~450 nm) into red photons (above ~680 nm). At the same time, the results showed that the integration of Si-ncs directly at low concentration (< 10 wt. %) in the active (PTB7/[70]PCBM)) layer also contribute to carrier generation and enhance high energy photons down conversion effect.

Acknowledgments: This work was partially supported by JSPS and a NEDO Project (Japan).