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Letter

Resonant infrared matrix-assisted pulsed laser evaporation of CdSe colloidal quantum dot/poly[2-methoxy-5-(2′-ethylhexyloxy)-1,4-(1-cyano vinylene) phenylene] hybrid nanocomposite thin films

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ABSTRACT

CdSe colloidal quantum dot / poly[2-methoxy-5-(2′-ethylhexyloxy)-1,4-(1-cyano vinylene)phenylene] hybrid nanocomposite thin films were deposited using resonant infrared matrix-assisted pulsed laser evaporation. The distributions of CdSe colloidal quantum dots within the polymer matrices of as-grown films were evaluated using transmission electron microscopy, and the optical properties of these films were determined by photoluminescence spectroscopy. These measurements demonstrate that: i) depending upon the deposition parameters used, the CdSe colloidal quantum dot distribution can be tuned between two morphology extremes, i.e. clustering or homogenous dispersion; and ii) the constituent materials of the nanocomposite are not damaged in any way that affects structural or optical properties by the deposition process. The demonstrated ability to control nanoparticle distribution within organic films has not been achieved by other deposition techniques and could enhance the performance of optoelectronic devices based on these materials.

In recent years, conjugated polymers have attracted significant attention for their potential application to light emitting diodes [1], solar cells [2,3], and photodetectors [4]. Unfortunately, in many of these applications, pure polymer devices have been unable to demonstrate sufficient efficiencies and stabilities to justify their use over conventional solid-state material systems [5]. One route to improving efficiency, particularly in solar cell applications, has been to incorporate organic small molecules, such as fullerenes [2], or inorganic nanomaterials, such as colloidal quantum dots (CQDs) [6], into the conjugated polymer bulk film. The morphology of these nanocomposites, especially the distribution of nanomaterials within the polymer, critically impacts exciton dissociation and charge transport in the film [2,3]. More specifically, as has been demonstrated in fullerene/conjugated polymer composite-based solar cells [2], the small molecule distribution inside the polymer bulk must form an interpenetrating network from electrode to electrode, and must also be separated by no more than one exciton diffusion length (5 to 20 nm) in order to effectively dissociate excitons and transport free carriers [5]. Potentially, inorganic CQDs offer exciton dissociation and charge transport benefits comparable to those of fullerene-based nanocomposites. In addition, by controlling the material composition and size of CQDs, they can be sensitized to wavelengths in the solar spectrum that are not well absorbed by their conjugated polymer hosts [6].

Despite these advantages, CQD/conjugated polymer nanocomposite films synthesized by spin-casting and drop-casting have not yielded the expected improvements in solar cell performance, which is due, in part, to the inability to control CQD distribution such that dot/polymer interfaces are within an exciton diffusion length across the entire film bulk [5]. The resonant infrared matrix-assisted pulsed laser evaporation (RIR-MAPLE) technique reported in this letter not only demonstrates this ability, but also provides a reproducible method for controlling CQD distribution within polymers such that the internal morphology of hybrid nanocomposites can be tuned to optimize the performance of different optoelectronic devices based on these materials. RIR-MAPLE is an extension of ultraviolet (UV)-MAPLE, and is an alternative for synthesizing CQD/conjugated polymer hybrid nanocomposite thin films. UV- and RIR-MAPLE deposit organic thin films by the laser ablation of a target comprising an organic material dissolved in a frozen solvent. Both MAPLE techniques have been demonstrated as effective tools for the deposition of several organic polymers [7–17], including poly[2-methoxy-5-(2′-ethylhexyloxy)-1,4-(1-cyano vinylene) phenylene] (MEH-CN-PPV) and poly[2-methoxy-5-(2′-ethylhexyloxy)-1,4-phenylene vinylene] (MEH-PPV) [8,9]. The unique approach reported in this letter is capable of controlling CQD/polymer hybrid nanocomposite morphology, namely the CQD distribution with the polymer bulk, via RIR-MAPLE deposition conditions, e.g., target composition and deposition sequence.

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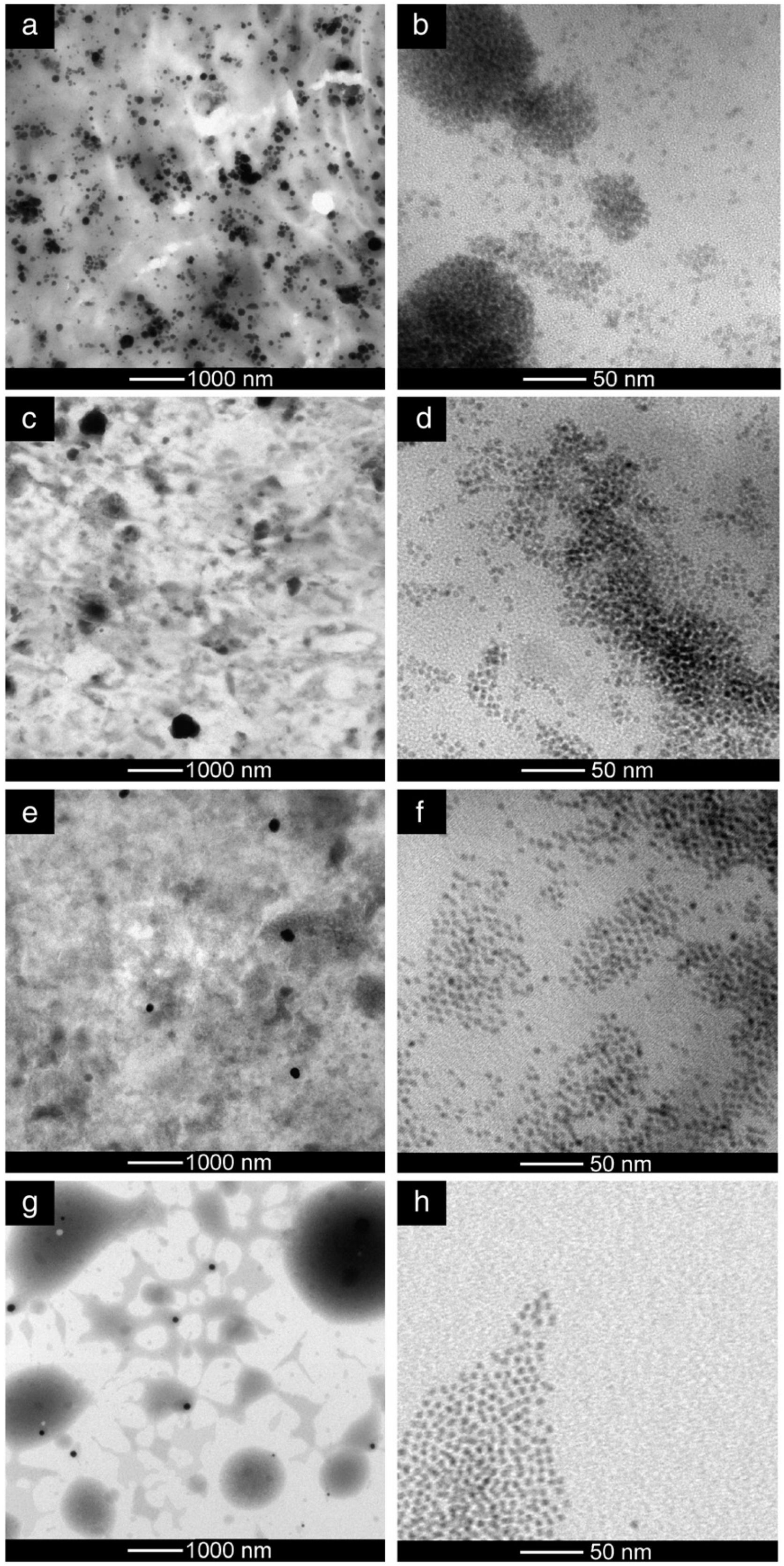

Fig. 1. TEM images of CdSe/MEH-CN-PPV hybrid nanocomposites. (a,b) 1:10 by weight, CdSe:MEH-CN-PPV simultaneously co-deposited from an emulsified target consisting of 1:5 benzyl alcohol:water. (c,d) 1:10, CdSe:MEH-CN-PPV sequentially deposited using a CdSe benzyl alcohol–water emulsion. (e,f) 1:10, CdSe:MEH-CN-PPV sequentially deposited using a CdSe toluene–water emulsion. (g,h) 1:10, CdSe:MEH-CN-PPV drop-cast.