PHOTOVOLTAIC DEVICES EMPLOYING TERNARY COMPOUND NANOPARTICLES

RELATED APPLICATIONS

[0001] The application claims priority to U.S. Provisional Patent Application Ser. No. 61/313,669, filed Mar. 12, 2010, which is herein incorporated by reference in its entirety.

STATEMENT OF GOVERNMENTAL SUPPORT

[0002] This invention was made with government support under Contract No. DE-AC02-05CH11231 awarded by the U.S. Department of Energy. The government has certain rights in the invention.

FIELD OF THE INVENTION

[0003] The present invention relates to the field of nanoparticles, and particularly relates to photovoltaic devices employing ternary compound nanoparticles.

BACKGROUND OF THE INVENTION

[0004] Colloidal semiconductor nanocrystals display a wealth of size-dependent physical and chemical properties, including quantum confinement effects, shape dependent electronic structure,[1, 2] and control over assembly through modification of surface functionalization.[3, 4] Photovoltaic devices are an easily recognized potential application for nanocrystals due, in part, to their high photoactivity, solution processability and low cost of production. Several schemes for using nanocrystals in solar cells are under active consideration, including nanocrystal-polymer composites,[5] nanoparticle array solar cells,[6] films of partially sintered nanoparticles,[7] and nanocrystal analogues to dye-sensitized solar cells.[8]

[0005] A persistent challenge for any nanoparticle-based solar cell is to take advantage of quantum confinement effects to improve the optical absorption process without overly hindering the subsequent transport of charge to the electrodes. Various binary semiconductor nanoparticles, like CdSe, CdTe, Cu_2S, InP, and InAs, have been explored for photovoltaic devices but the reported efficiencies remain low, mostly limited by poor charge transport between the nanocrystals.[5, 7-12] With so many parameters to adjust in terms of size and shape, little work has focused on ternary or quaternary compositions of nanoparticles for solar cells. Yet it is well known from thin film solar cell studies that such compositional tuning can sometimes yield significant improvements in performance.

[0006] The Pb chalcogenide family of nanocrystals has been actively investigated for nanocrystal solar cell applications because they have such large exciton Bohr radii (PbS 18 nm, PbSe 47 nm, and PbTe 150 nm). In the limit where the nanocrystals are only a tenth or so of the bulk exciton diameter, electrons and holes can tunnel through a thin organic surface coating, and therefore strong electronic coupling between particles facilitates transport of charge between nanocrystals. So far, solar cells based on binary compositions of PbSe and PbS nanocrystals have been investigated.

[0007] PbSe nanocrystal solar cells generate larger short circuit photocurrents while PbS nanocrystal devices with similar bandgap have shown a larger V_{OC}.[6]

[0008] Moreover, the properties of PbS and PbSe lead to an ideal substitutional alloy: the atomic anion radii are within 15% of each other, the lattice mismatch factor is only 2% between PbS and PbSe (see Supporting Information for the similarity of the XRD patterns), and, of course, the anions are isovalent.

SUMMARY OF THE INVENTION

[0009] The present invention provides a photovoltaic device. In an exemplary embodiment, the photovoltaic device includes a substrate having a thin film disposed thereon, where the thin film includes alloyed ternary nanocrystals. In an exemplary embodiment, the thin film includes a photoactive layer. In an exemplary embodiment, the photoactive layer includes at least a single layer of the alloyed ternary nanocrystals. In an exemplary embodiment, at least a portion of the nanocrystals includes a material selected from the group consisting of metals and Group II-VI, Group III-V, and Group IV semiconductors and alloys thereof. In an exemplary embodiment, the nanocrystals include a lead chalcogenide or combinations thereof. In an exemplary embodiment, the nanocrystals include a PbSSe.

[0010] The present invention provides also provides a method of making ternary compound nanocrystals. In an exemplary embodiment, the method includes (1) degassing a solution of PbO, oleic acid and 1-octadecene (ODE) in a container, (2) heating the solution in the container, (3) injecting a first mixture of trioctylphosphine (TOP):Se solution, TMS2S, diphenylphosphine (DPP) and ODE into the heated solution, thereby forming a second mixture in the container, (4) adding ODE to the second mixture in the container, (5) growing the nanocrystals in the second mixture in a reaction in the container, and (6)_quenching the reaction, thereby resulting in precipitated nanocrystals in the container. In a further embodiment, the present invention further includes purifying the precipitated nanocrystals.

[0011] In an exemplary embodiment, the heating step includes heating the solution at approximately 150° C. In an exemplary embodiment, the heating includes heating the solution for approximately 1 hour.

[0012] In an exemplary embodiment, the growing includes growing the nanocrystals at approximately 150° C. In an exemplary embodiment, the growing includes growing the nanocrystals for approximately 90 seconds.

[0013] In an exemplary embodiment, the quenching includes (a) placing the container in a room-temperature water bath and (b) introducing anhydrous hexane into the container, thereby resulting in the precipitated nanocrystals.

[0014] In an exemplary embodiment, the purifying includes (a) twice precipitating the nanocrystals in hexane/ethanol and (b) precipitating the nanocrystals in hexane/acetone.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1A illustrates a photovoltaic device in accordance with an exemplary embodiment of the present invention.

[0016] FIG. 1B illustrates a photovoltaic device in accordance with an exemplary embodiment of the present invention.

[0017] FIG. 2A is a flowchart in accordance with an exemplary embodiment of the present invention.

[0018] FIG. 2B is a flowchart in accordance with a further embodiment of the present invention.