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NEW APPROACH TO NATURALLY FORM DESIGN NANOSTRUCTURED SEMICONDUCTOR BULK PN HOMOJUNCTIONS FOR OPTO-ELECTRONIC DEVICES

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Planar semiconductor pn junctions constitute an integral part of most optoelectronic devices; they generally require high quality expensive crystals. Bulk heterojunction (BHJ) configuration can circumvent cost, complexity, flexibility and scale-up challenges of conventional pn junctions. Current BHJ structures physically mix organic or inorganic colloidal materials, which invariably create interface mismatch and low doping issues. This paper introduces a radically different thermodynamically-driven, single-step electrodeposition approach; it naturally creates self-stabilized bulk homojunctions, exemplified here by two copper-indium-selenide (CISe) compounds. The resulting film comprises interconnected 3D network of highly-ordered, sharp, abrupt truly-nanoscale pn BHJs; these exhibit unusual electro-optical properties, long lifetime and quantum confinement effects. Unlike colloidal nanocrystals, the CISe nanocrystals are highly doped. Their ordered nanoscale morphology facilitates interpenetration for fast, efficient carrier separation and transport; minimizes recombination and essentially performs the same functions as the high-end, crystalline planar pn junctions. This totality manifests as a significant advance in electrochemical processing of semiconductors, it discloses a generally accessible, very low-cost platform method to create high quality nanocrystalline pn BHJ absorbers with various chalcogenides. These inorganic BHJs can be directly used in devices. With addition of finely band-aligned contact electrodes, these BHJs can transition into high performance devices for LED or solar photovoltaic devices or serve as photoelectrodes for fuel generation. Furthermore, they can be roll-to-roll processed in simple flexible thin-film form factor for easy scale-up.

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