

Materials and Device Design for Thin-film intermediate band solar cells

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Graphical Abstract

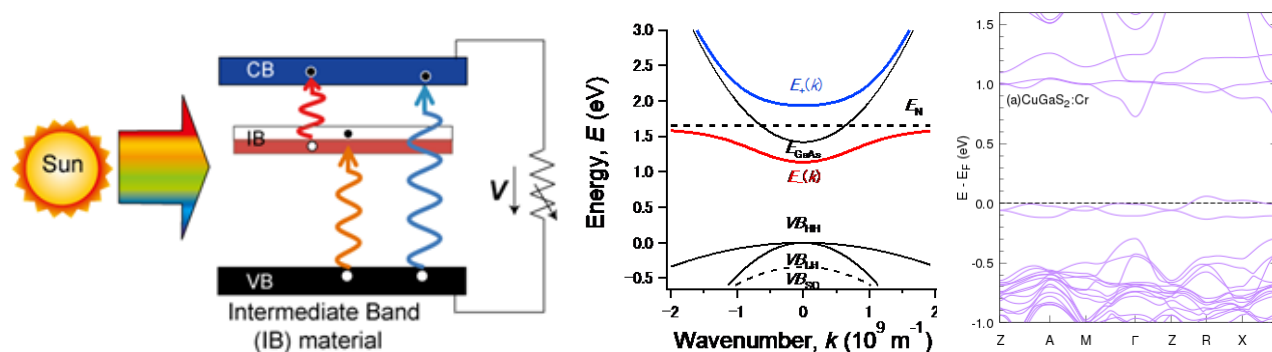


Fig. 1. (a) Intermediate band solar cell: Schematic diagram of multi-step light absorption, (b) Electronic band structure of N-doped GaAs calculated using band anti-crossing (BAC) model, and (c) Electronic band structure of Cr-doped CuGaS_2 .

Abstract

Intermediate band solar cells (IBSCs) are expected to exceed the theoretical conversion efficiency of single junction solar cells [1] due to the build-up of long-wavelength photocurrent assisted by two-step photon absorption (TSPA). However, the TSPA in experiments of below-bandgap solar radiation has been too weak producing only small photocurrent increments in present materials including III-V quantum dots [1] and III-V dilute nitrides [2].

The key materials parameters to improve the IBSC performances are: (1) a reasonably wide-bandgap semiconductor material that can reduce the loss of hot-electron energies produced by the short-wavelength solar spectrum photons, and (2) a suitable intermediate band (IB) or states existing roughly around the position of 1/3 or 2/3 of the bandgap that can increase the short circuit current, I_{sc} , by absorbing long-wavelength solar photons. In order for an efficient TSPA production, it is

required that the Fermi level E_F stays inside the IBs. On the other hand, the key device requirement is the perfect electrical isolation of the IB from the metal contacts which only allows the selective collection of photo-carriers from the band edges. The design of a suitable energy barrier layer can realize the electrical isolation by blocking the escape pathways of the IB electrons to the contacts.

In this talk, we focus on two compound semiconductor systems, promising for high efficiency IBSC application, based on calculation and experiments: III-V GaAs-base dilute nitrides [2], and I-III-VI₂ CuGaS₂-based chalcopyrite sulphides [3]. In the prior, the splitting of the conduction band (CB) into two sub-bands makes them promise for IBSC application, and the magnitude of bandgap between them can be artificially designed by the amount of nitrogen. In the latter, deep impurity states are promoted into intermediate bands by raising the concentration above Mott transition level inside a wide bandgap CuGaS₂ host. We discuss about the device design and characteristics of the respective systems, and their future outlook.

Keywords: Intermediate band solar cells, III-V dilute nitride and chalcopyrite semiconductors, density functional theory.

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Biography of Presenting Author



Nazmul Ahsan received the M.S. and Ph.D. degrees in electronic engineering from The University of Tokyo, Japan, in 1999 and 2002, respectively. He is currently a Research Associate Professor at the Research Center for Advanced Science and Technology (RCAST) at the University of Tokyo. His research interests include ultra-high-efficiency photovoltaic devices, spintronic devices, Molecular Beam Epitaxy of compound semiconductors, Materials design and characterization.

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