[Energy Distinguished Lecture Series]

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Bandgap and Interface Engineering of Halide Perovskites: From Single-Junction Devices to Next-Generation Tandem Solar Cells

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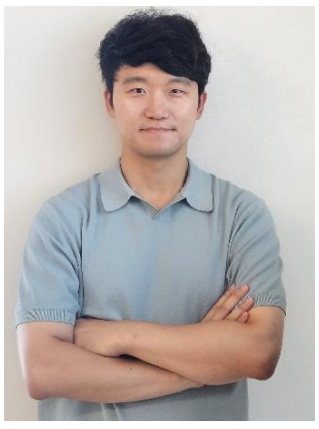
Abstract

The transition toward carbon-neutral energy systems requires photovoltaic technologies that combine high power-conversion efficiency with low-cost manufacturing and application versatility. Although crystalline silicon photovoltaics currently dominate the market, their performance is approaching the practical limit of single-junction devices, while their energy-intensive processing and rigid form factors constrain their use in emerging applications. Metal halide perovskites have attracted considerable attention as next-generation photovoltaic absorbers owing to their strong optical absorption, compositionally tunable bandgaps, long carrier diffusion lengths, high carrier mobilities, and compatibility with low-temperature processing. Single-junction perovskite solar cells have achieved a certified power-conversion efficiency of 27.3%, approaching the efficiency level of established silicon technologies. Nevertheless, single-junction devices remain fundamentally limited by thermalization losses from high-energy photons and transmission losses from photons with energies below the absorber bandgap.

Tandem architectures provide an effective pathway to overcome these spectral losses by combining complementary photoabsorbers with different bandgaps. Realizing high-performance perovskite-based tandems, however, requires the simultaneous optimization of bandgap, crystallization, defect chemistry, interfacial energetics, charge-selective contacts, and optical management. In this presentation, our progress in bandgap and interface engineering of halide perovskites will be discussed, spanning wide-bandgap Sn-based perovskites, narrow-bandgap Sn–Pb absorbers, and semitransparent perovskite sub-cells. Particular emphasis will be placed on molecular additive engineering, interfacial defect passivation, energetic reconstruction, and charge-transport-layer design for reducing voltage losses and improving device stability and reproducibility. These material and device strategies are further extended to lead-free all-perovskite and visibly transparent perovskite/organic tandem solar cells.

Finally, the remaining challenges and opportunities for developing efficient, stable, and application-oriented perovskite-based tandem photovoltaics will be discussed.

Brief Bio



Professor Dong-Won Kang received his B.S. degree in Electrical Engineering and Ph.D. degree in Electrical and Computer Engineering from Seoul National University, Republic of Korea, in 2007 and 2013, respectively. He subsequently worked as a postdoctoral researcher at Tokyo Institute of Technology, Japan, from 2013 to 2015. He began his academic career as an Assistant Professor in the Department of Solar Energy at Cheongju University in 2015 and joined Chung-Ang University in 2018, where he is currently a Professor in the School of Energy Systems Engineering. His research focuses on advanced materials and device engineering for next-generation energy conversion technologies, with particular emphasis on bandgap, crystallization, and interface engineering of halide perovskites for single-junction and tandem photovoltaics. His recent research encompasses wide-bandgap Sn-based perovskites, narrow-bandgap Sn–Pb perovskites, semitransparent photovoltaic sub-cells, and all-perovskite and perovskite/organic tandem solar cells. His broader research interests include organic and inorganic optoelectronic materials and integrated energy conversion–storage devices. He has published more than 164 international journal papers and is an inventor on more than 25 filed or granted patents.

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