Advances in Light-harvesting Materials: From World-record Perovskite Solar Cells to X-ray Imaging Scintillators with Exceptional Resolution

Omar F. Mohammed

Division of Physical Sciences and Engineering, King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, KSA

Abstract : The process of separating and collecting photo-generated charge carriers in light-harvesting devices is hindered by losses and ambiguous dynamical events that occur at the surfaces and interfaces of the absorber layers.[1-3] These events occur at ultrafast timescales and can only be selectively visualized in space and time using scanning ultrafast electron microscopy, which is the only technique capable of surface-selective visualization of light-triggered carrier dynamics at nanometer and femtosecond scales. This method involves exciting the surface of the photoactive materials with a clocking optical pulse and directly imaging the photo-induced changes using a pulsed electron beam that generates secondary electrons with a few electron volts of energy. These electrons are emitted from the very top surface of the material in a manner that is highly sensitive to the localization of the electron and hole on the photoactive material surfaces. This powerful technique along with ultrafast laser spectroscopy allow us to directly and precisely investigate and decipher the trajectory of charge carriers on materials surfaces and interfaces in real space and real time. Through this work, we have optimized the properties of photoactive materials for applications in light-harvesting devices that led to the world-record solar cell devices based on perovskite crystals. Moreover, we have clearly demonstrated in space and time how the surface orientations, surface oxidation and passivation can significantly impact the overall dynamical processes of photo-generated charge carriers in optoelectronic materials.[4-5] Finally, I will talk about our recent ground-breaking work in X-ray imaging technology that include cutting-edge materials discovery, heavy-atom engineering, state-of-the-art characterization and efficient (nearly 100%) interfacial energy transfer between sensitizers and scintillators that has led to the development of novel X-ray imaging screens including novel top-filter-bottom sandwich structure for dual-energy X-ray imaging with outstanding sensitivity, ultralow detection limit, unprecedented spatial imaging resolution and low-cost fabrication, with potential applications in medical imaging, industrial monitoring and security screenings. [6-10]

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