Perovskite Quantum Dots: A New Absorber Technology with Unique Phase Stability for High-voltage Solar Cells

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The newly rediscovered perovskite semiconductor system has the potential to be extremely transformative for all optoelectronic devices, especially photovoltaics (PVs). Perovskite semiconductors of the form $APbI_3$ where A is a large +1 charged cation, typically Cs, methylammonium, or formamidinium have had a huge resurgence among materials scientists for outstanding PV properties despite being overlooked for decades. Semiconductors containing the latter two A-site cations listed are *hybrid organic-inorganic materials*, and as such, are far less understood compared to conventional all inorganic or even organic material systems. Regardless of this spotty formal understanding, lead-halide perovskites have very rapidly been optimized to power conversion efficiency levels on par with all other materials even with extensive history of research. Perovskites show a unique tolerance to crystalline defects that cause trouble in most other semiconductors. Therefore the potential offered is that very high efficiency PVs can be fabricated in extremely fast and inexpensive ways, thus offering a revolution for the solar industry and a direct route toward producing the world's energy with a simple and clean technology. Long-term durability of the devices is the critical remaining challenge to be solved. Two examples of major instabilities in device performance are the volatility of the organic cation and the specific crystal habit in which the material embodies.

Nanoscale versions (often termed quantum dots (QDs)) of the all-inorganic metal halide perovskite ($CsPbI_3$) tend to retain the desired cubic phase due to strain effects at the surface of the QDs whereas conventional films of the same material "relax" to an orthorhombic structure at room temperature. Therefore these QDs potentially solve both of the instability issues. The cubic $CsPbI_3$ QD cells operate with a rather remarkable open-circuit voltage of >1.2 volts and have produced power conversion efficiencies over 13%. This customizable new nanomaterial system has incredible potential for many applications in optoelectronics, including photovoltaics, LEDs, displays and lasers. We describe the formation of α-$CsPbI_3$ QD films with long range electronic transport that retain the high temperature phase in ambient conditions making up the active layer in optoelectronic devices. Perspectives on how this technology can become transformative will be discussed.