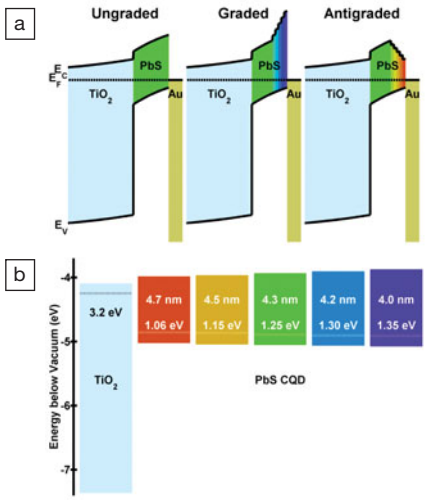
Energy Focus

Quantum dot funnels increase solar-cell fill factor

Quantum dot funnels—which are devices comprising graded layers comprising quantum dots of different sizes, and therefore bandgaps—offer the possibility of funneling energy toward a suitable acceptor. In the September 14 issue of *Nano Letters* (DOI: 10.1021/nl201682h; p. 3701), I.J. Kramer, E.H. Sargent, and colleagues at the University of Toronto constructed a new solar cell designed around this concept where photoelectrons are efficiently transferred from their source to an electron acceptor. PbS quantum dot funnels were fabricated on TiO_2 electrodes. The resulting solar cells define a path to achieving further improvements in the fill factor of colloidal quantum dot photovoltaics—a crucial determinant of the devices' performance.

The researchers created three funnel types, two of which were graded by their bandgap to promote or discourage charge-carrier collection, and one control. These were graded, antigraded, and ungraded, respectively. The researchers started with a base layer of glass, coated in SnO_2/F and then applied a commercially available TiO_2 paste. Multilayer spin coating of solutions of quantum dots generated a graded funnel with three layers of 4.3 nm diameter CQDs (colloidal quantum dots), one layer of 4.2 nm, and one layer of 4.0 nm. Ungraded controls comprised five layers of 4.3 nm CQDs, while antigraded funnels consisted of three layers of 4.3 nm, one layer of 4.5 nm, and one layer of 4.7 nm diameter CQDs. Each CQD layer was 25 nm thick. Finally, the prepared devices were coated with layers of thin films of gold and silver.

Ungraded control funnels provided a fill factor of 49%, graded



(a) Spatial band diagrams of ungraded, graded, and antigraded colloidal quantum dot (CQD) solar cells. Color coding corresponds to larger bandgaps (more blue/violet) and smaller bandgaps (more yellow/red). (b) Detailed band alignment for the TiO_2 and PbS CQD materials used, also employing the same color coding scheme. Reprinted with permission from *Nano Lett*. **11** (9) (2011), DOI: 10.1021/nl201682h; p. 3701. © 2011 American Chemical Society.

https://doi.org/10.1557/mrs.2011.281 Published online by Cambridge University Press

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funnels 54%, and antigraded funnels only 37%, where the fill factor provides a measure of the efficiency of the cell. That a 5% increase in fill factor was achieved on changing the structure from ungraded to graded is key to future applications, and the researchers predict the CQD funnels can improve systems with high base fill factors. Additional theoretical modeling shows that such benefits could apply to high-efficiency photovoltaics, as well as the 2–3% efficiency technologies on which these funnels were tested. The research team suggests that CQD funnel solar cells could enable higher power-per-square-foot densities, lowering the square footage of solar cells needed to power a building.

Benjamin Scheiner

Thin-film heterostructures of Fe- and Co-$BaTiO_3$ exhibit interface multiferroicity at room temperature

Materials possessing coupled room-temperature ferromagnetic (FM) and ferroelectric (FE) order are currently the subject of intense research for use in spintronic memories that store information through charge and spin. Single-phase materials displaying such multiferroic order are exceedingly rare in nature, so attention has shifted to artificially grown thin-film FM and FE heterostructures. In the October issue of *Nature Materials* (DOI: 10.1038/NMAT3098; p. 753), a group led by M. Bibes and A. Barthélémy at the CNRS/Thales laboratory in Palaiseau, France, reports on room-temperature interfacial multiferroicity in $BaTiO_3$ thin films and substrates covered by Fe and Co layers.

The research team deposited thin-film heterostructures consisting of Fe/BTO or Co/BTO onto a half metallic $La_{0.67}Sr_{0.33}MnO_3$ (LSMO) layer to form a magnetic tunnel junction. They then performed magnetoresistance and x-ray resonant magnetic scattering (XRMS) measurements to probe the magnetic structure of the Fe/BTO and the Co/BTO interfaces. The researchers found that the magnetoresistance of the junction depends on the orientation of the FE polarization in the BTO layer, which they interpret as a modulation of the spin polarization of the adjacent Fe and Co layers. The XRMS results also exhibit an asymmetry and hysteresis that corresponds to an induced interfacial magnetic moment in the BTO layer at room temperature. To better understand these observations, the researchers conducted first-principles electronic-structure calculations and determined that moments of −0.07 μB/Ti atom and

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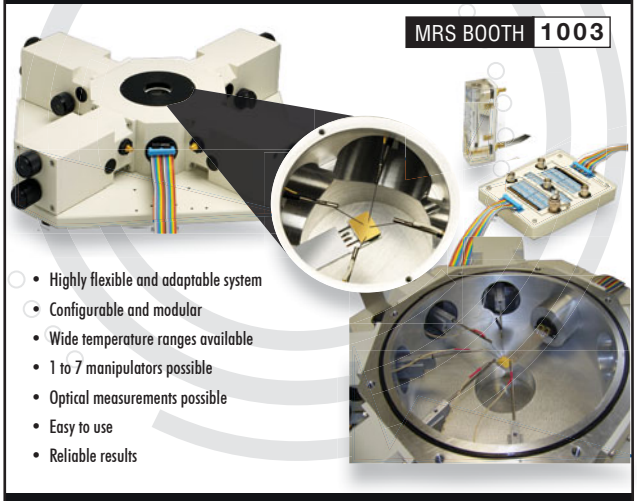

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