Quantum Dots and Nanowires Demonstrate Potential for Efficient Solar Cells

As solar power technology becomes more widely adopted, intensive research efforts are underway to find the next generation of inexpensive but efficient photovoltaics beyond crystalline silicon. One example is quantum-dot-sensitized solar cells, which harvest sunlight using quantum dots adsorbed on a network of TiO_2 nanoparticles. However, the disordered structure of these mesoscopic TiO_2 networks can allow photogenerated electrons to recombine with holes, which reduces overall efficiency. K. Leschkies and colleagues at the University of Minnesota have combined quantum dots (QDs) with ordered arrays of single-crystal semiconductor nanowires to produce photovoltaic devices in which electron–hole recombination is significantly reduced.

As reported in the June issue of *Nano Letters* (p. 1793; DOI: 10.1021/nl070430o), the research group theorized that the ordered nanowire array would more efficiently guide photogenerated electrons to the photoanode than disordered TiO_2 networks. To fabricate the device, the researchers began by growing ZnO nanowires onto a transparent, conducting SnO_2 substrate. The wires had lengths between 2 μm and 12 μm and diameters of 75–125 nm. Separately, the group prepared CdSe nanocrystals approximately 3 nm in diameter, which they capped with mercaptopropionic acid (MPA). By immersing the nanowires in a methanol dispersion of the QDs, the researchers were able to attach the QDs to the nanowires. Treating the nanowires with oxygen plasma before immersion significantly increased the attachment efficiency. To complete the device fabrication, the group assembled the QD-decorated nanowire photoanode face-to-face with a SnO_2 photocathode, filling the 25-μm space between the electrodes with a hybrid liquid electrolyte.

The resulting devices displayed a photovoltaic effect and clear evidence that photogenerated electrons in the QDs were injected into the nanowires. While the overall energy-conversion efficiency of the system was less than 0.5%, this was limited primarily by the surface area of the nanowires. The internal quantum efficiencies were as high as 58%, indicating that the nanowires efficiently collected and guided photogenerated electrons. The researchers reported that their solar cells were stable for a few hours to a few days in air. They said that liquid electrolyte is known to degrade quantum dots over time, and that optimization of the cells will require a transition to a different electrolyte, which will be the subject of future work. Given these results, devices based on single-crystal nanowires sensitized with solar-tailored quantum dots may someday become the next-generation photovoltaic system of choice.

COLIN MCCORMICK

230-nm Wide Laser Tunability Range Obtained in Tm:$LiLuF_4$ Crystal

Solid-state lasers based on thulium and emitting at around 1.9 μm are interesting as they can be continuously tuned in wavelength from 1.8 μm to 2 μm. They provide an appropriate tool for high-resolution molecular spectroscopy, atmospheric remote sensing, and medical surgery, as several absorption lines of chemical compounds, such as H_2O, CO_2, and NO_2, are present in this range. Tm-doped active media can be pumped by commercially available high-power InGaAs laser diodes at wavelengths around 790 nm, allowing the implementation of efficient, compact, and rugged laser sources.

N. Coluccelli and co-workers from the Politecnico di Milano and the Istituto di Fotonica e Nanotecnologie–CNR in Milan, Italy, and F. Cornacchia and co-workers from the Pisa University and National Enterprise for Nano Science and Technology–INFM Pisa, Italy, have reported in the July issue of *Optics Letters* (p. 2040) room-temperature continuous-wave laser action in Tm:$LiLuF_4$ crystals with a tunability range of 230 nm, an output power of 1.15 W, and a slope efficiency with respect to the incident power up to 46%, which represents, the researchers said, the highest value ever demonstrated with diode-pumped Tm-doped fluoride crystals.

The researchers grew crystals of Tm:$LiLuF_4$ with scheelite structure (with two axes of equal length a, and a third of length c) from the melt by the Czochralski technique at 860ºC in a high-purity (99.999%) argon atmosphere from LiF and LuF_3 powders and adding 8%, 12%, and 16% mol of TmF_3 powder to the melt. Tm^{3+} substituted Lu^{3+} in the structure with a segregation coefficient close to one. The room-temperature absorption spectrum of Tm^{3+} in these crystals in the 800 nm region shows the most intense peak at 779.8 nm (FWHM = 7.6 nm) for the polarization of the light parallel to the c-axis ($E||c$), a peak particularly suitable for diode pumping. The researchers found the maximum values for the emission cross section at 1911 nm for the $E||a$ polarization (0.4×10^{-20} cm^2) and at 1886 nm for the $E||c$ polarization (0.31×10^{-20} cm^2). The researchers performed the laser experiments in a three-mirror folded cavity using a cw AlGaAs laser diode as the pump source with a linearly polarized emission tuned at ~780 nm and a maximum output power of 3.2 W as the pump source. The sample was placed inside the resonator in such a way to take advantage of the absorption cross section obtained along the $E||c$ polarization. It was oriented at Brewster's angle to minimize Fresnel losses of both the pump and laser beams originating from the air- crystal interfaces. A 12% Tm doping level provided the highest output power of 1.15 W (at 3.2 W pump power) using a 5% output coupler. With a 1% output coupler, the slope efficiency slightly increased from 43% to 46%, although the maximum output power was only of 1.05 W at 3.2 W pump power. By inserting a 2-mm thick birefringent quartz plate, oriented also at Brewster angle along the longest arm of the resonator, the researchers investigated the emission tuning range of Tm:$LiLuF_4$ crystals, obtaining the widest tuning range in a 12% Tm-doped $LiLuF_4$ crystal, from 1826 nm to 2056 nm.

JOAN J. CARVAJAL

Effects of Hydration on Electronic Properties of C_{60} Fullerene Accurately Calculated from First Principles

The optical efficiency of semiconducting nanoparticles has triggered industrial interest for their incorporation into sensing and other electronics applications. Fullerenes, for example, which have been shown to increase the biostability of electrochemical sensors, are under investigation as Raman-active nanosensors and cytotoxic agents, and are considered one of the most versatile biologically important nanoparticles. However, biological applications typically include an aqueous environment. Consequently, an understanding of the interactions between nanoparticles and water and their effect on optical properties is paramount. Recently, R. Rivelino and F. de Brito Mota from Instituto de Fisica, Universidade Federal da Bahia, Brazil, used a sequential Monte Carlo/density functional theory (MC/DFT) scheme to examine the effects of hydration and the dielectric screening of water on the C_{60} bandgap and density of states under ambient conditions.

As described in the June issue of *Nano Letters* (p. 1526; DOI: 10.1021/nl070308p), Rivelino and de Brito Mota used an atomistic model consisting of a periodic cell with one C_{60} molecule solvated by 1000 water molecules at standard temperature and pressure. The dispersion interaction