the transport properties of the composite material despite taking up only 3% of the total sample volume.

"$Cu_{1.97}Ag_{0.03}Se$ is a useful thermoelectric, which is intended to be used above the superionic phase transition temperature, at 390 K, where the material consists of a single phase," said Snyder. "The research we carried out for this paper below the superionic phase transition temperature is more of an academic exercise, demonstrating that we can determine the contributions of individual phases to bulk properties. It is really interesting to see how even a small impurity phase can dominate the overall behavior of a composite material."

Understanding the contribution of individual phases to the overall properties of thermoelectric composite materials will guide researchers in their quest to optimize this class of materials and to further the implementation of thermoelectrics in everyday applications. The newly discovered use of effective medium theory will certainly play an important role in future studies, as Tristan W. Day, who is the first author of this study, confirmed.

"What we have learned in this study, with regard to using effective medium theory in reverse, is useful for studying other composite materials as well. The methodology can be applied to our work on organic/inorganic thermoelectrics, for example," said Day.

Birgit Schwenzer

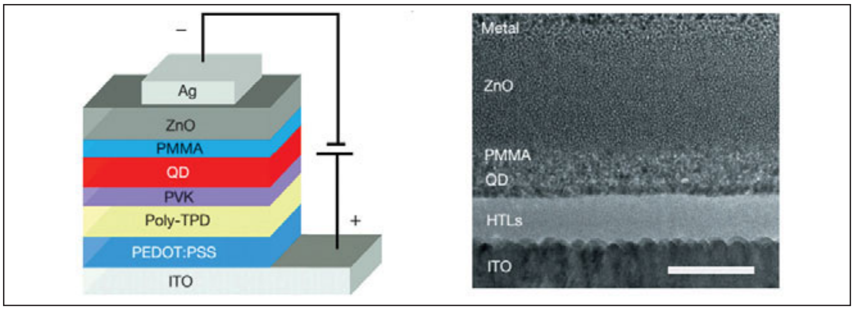
Energy Focus

Insulator triggered charge balance for high-performance QLEDs

Vacuum deposition is the primary technique currently employed by industry for producing commercial light-emitting diodes (LEDs) as their performance is superior to that of solution-processed LEDs. However, a team of nine scientists from China led by Yizheng Jin and Xiaogang Peng at Zhejiang University have recently taken an important step forward in the development of solution-processed LEDs, as reported in the November 6, 2014, issue of *Nature* (DOI:10.1038/nature13829; p. 96). The research team achieved this by using nonblinking quantum dots (QDs) with a photoluminescence quantum yield above 90%. As Peng explained, "Blinking quantum dots are simply not well-suited for the development of highly efficient LEDs."

Previous solution-processed LEDs have suffered from several performance deficiencies, including high turn-on voltages, low power efficiency, short lifetimes, and significant roll-off. According to Peng, "An LED with significant roll-off is not useful for many applications, because they are less efficient when operated at high current densities."

The deep-red LED designed by Peng, Jin, and their colleagues is an eight-layer device, as shown in the accompanying figure. The device has a low turn-on voltage and high power efficiency because of the highly efficient injection of holes into the QD layer from the bilayer located underneath. Meanwhile, ZnO nanocrystals are deposited above the QD layer to act as electron-transport interlayers, because they enable high electron mobility.



Transmission electron micrograph (right) shows the structure of the high-performance light-emitting diode (LED) that incorporates nonblinking quantum dots; scale bar = 100 nm. The eight layers consist of indium tin oxide (ITO), poly(ethylenedioxythiophene):polystyrene sulfonate (PEDOT:PSS), poly(*N,N*'-bis(4-butylphenyl)-*N,N*'-bis(phenyl)-benzidine) (Poly-TPD), poly(9-vinylcarbazole) (PVK), CdSe-CdS core–shell quantum dots (QDs), ZnO nanoparticles, and silver (Ag). Reproduced with permission from *Nature* **515** (7525) (2014), DOI: 10.1038/nature13829; p. 96. © 2014 Macmillan Publishers Ltd.

The layer of PMMA between the QD and ZnO layers was found to be extremely important, because it acts as an insulator. When the PMMA layer is absent, excess electron current is injected into the QD layer, resulting in poor stability, a reduction in performance, and a 50% reduction in the initial luminance within 10 hours when operated at 6600 cd m^{-2}. To put this in perspective, Jin said that "indoor lighting [white light] requires a brightness of roughly 5000 cd m^{-2} while displays range from 100 to 1000 cd m^{-2}." When a thin PMMA layer is deposited into the device, the half lifetime for the initial luminance is increased to 95 hours when operated at 10,600 cd m^{-2}. Based on this finding, it is predicted that the half lifetime of this same device would be over 100,000 hours if operated at 100 cd m^{-2}. Most importantly, the device with the PMMA layer is easily reproducible and yields high performance that is very comparable to vacuum-deposited organic LEDs.

This initial work relied on QDs with an emission band in the deep-red region. However, the researchers see no fundamental difficulties that would preclude them from using QDs with other emission bands. In fact, they are already testing the system with other colors, because, as Peng explained, "In today's energy-sensitive society, high-performance LEDs fabricated with inexpensive techniques might play a critical role in multiple industrial sectors, such as displays and lighting."

Anthony S. Stender