New OLETs emit light more efficiently than equivalent OLEDs

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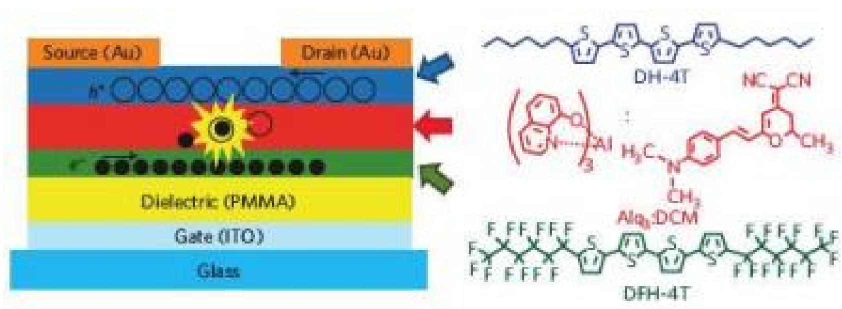

The new OLET, which is 10 times more efficient than any other reported OLET, has a trilayer structure. Electrons from the green layer and holes from the blue layer move to the middle red layer, where excitons are formed and light is emitted. Image copyright: Nature Publishing Group.

(PhysOrg.com) -- Already, organic light-emitting diodes (OLEDs) are becoming commercialized for light display applications due to their advantages such as low fabrication costs and large-area emission. But OLEDs also have intrinsic efficiency limitations due to their structure, which might limit their future development in terms of brightness. Now, a team of researchers has found that another organic semiconductor-based device, the organic light-emitting transistor (OLET), can dramatically increase the efficiency of OLEDs since OLETs have the structure of a transistor rather than a diode. In their recent study, the researchers have created OLETs that are 10 times more efficient than any previously reported OLET, as well as more than twice as efficient as an optimized OLED made with the same materials.

The researchers, Raffaella Capelli, et al., from the Institute for Nanostructured Materials (ISMN) in Bologna, Italy, and the Polyera Corporation in Skokie, Illinois, USA, have published their results in a recent issue of Nature Materials.

As the researchers explain, OLED technology is by far the most developed of the two organic semiconductor-based devices. But the biggest drawback to using OLEDs for light display applications is that they intrinsically suffer from photon loss and exciton quenching. Both effects are a direct result of the structure of OLEDs: The close spatial proximity of the electrical contacts and the light-generation region causes some emitted photons to be absorbed, resulting in photon loss. Similarly, the largest quenching effect in OLEDs, called exciton-charge quenching, reduces the number of excitons, and occurs due to a spatial overlap of excitons and charges.

Because OLETs have a transistor-based structure, researchers have recently been looking for ways to suppress these deleterious effects inherent in the OLED architecture. So far, they have only managed to prevent one type of quenching called exciton-metal quenching, which was done by moving the light-emitting area further away from the electrodes. However, the other effects still remained, so that the best OLETs only achieved an efficiency of no more than 0.6%.

In the new study, the researchers designed an OLET that could avoid photon losses and the two types of quenching. In demonstrations, the new OLETs achieved efficiencies of 5%. In comparison, equivalent OLEDs had efficiencies of just 0.01%, while optimized OLEDs with the same emitting layer as the OLETs achieved efficiencies of 2.2%, with the difference being due to their diode structure. (Although 2.2% is the highest reported efficiency for OLEDs based on fluorescent emitters, researchers have recently reported OLEDs based on phosphorescent emitting material with an efficiency on the order of 20%.)

The researchers call their novel device a tri-layer field-effect OLET due to its three organic semiconducting layers: a top 15-nm-thick p-channel layer that transports holes, a 40-nm-thick middle layer that emits light (the "exciton formation zone"), and a bottom 7-nm-thick n-channel layer that transports electrons. In this set-up, electrons and holes move from their respective layers to the middle layer, where excitons are formed and light is emitted. The three semiconductor layers are positioned on a three-layer substrate of glass, indium tin oxide, and PMMA, and two gold electrodes on top complete the design.

The trilayer architecture offers several advantages. For one, the light-formation and light-emitting regions are located far enough away from the electrodes so that photon losses at the electrodes and exciton-metal quenching are prevented. Also, the light-emitting region is physically separated from the charge flows, which prevents exciton-charge quenching. For these reasons, the researchers describe the tri-layer OLET as a "contactless OLED," where these deleterious effects are intrinsically prevented. In addition to these improvements, the researchers predict that the efficiency of the new OLET should be able to be increased even further with further adjustments, such as decreasing the operating voltage and carefully tuning every part of the structure.

"Despite the necessary technical improvements, we believe that our tri-layer OLETs represent a viable route to increase even further the device efficiency," Capelli, a researcher at ISMN, told *PhysOrg.com*.

Overall, the scientists hope that the OLET represents a route toward developing practical organic light-emitting devices with unprecedented efficiency. The device could offer the potential for many applications, such as intense nanoscale light sources and optoelectronic systems.

"The OLET is a new light emission concept, providing planar light sources that can be easily integrated in substrates of different natures (silicon, glass, plastic, paper, etc.) using standard microelectronic techniques," said Michele Muccini, a researcher at ISMN. "Our devices provide planar micrometer-size light sources that might enable organic photonic applications like integrated on-chip bio-sensing and high resolution display technology with embedded electronics. Moreover, a long term perspective for OLETs could be related to the realization of an electrically pumped organic laser."

More information: Raffaella Capelli, et al. "Organic light-emitting transistors with an efficiency that outperforms the equivalent light-emitting diodes." *Nature Materials*. Doi:10.1038/NMAT2751