Nano-LEDs emit full visible spectrum of light

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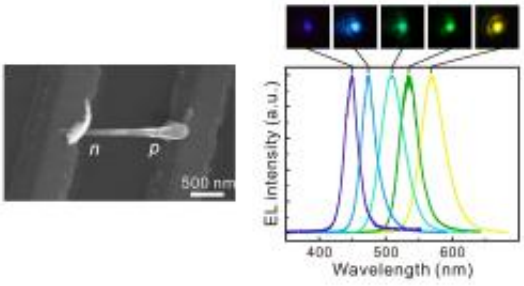

(Left) A single nanodisk-nanorod LED viewed with a field-emission scanning electron microscope. (Right) Some colors of light emissions from nanodisk-nanorod LEDs - violet, blue, cyan, green, and yellow - viewed with an optical microscope. Image credit: Lu, et al. ©2011 American Institute of Physics

(PhysOrg.com) -- Physicists from Taiwan have designed and fabricated nano-sized light-emitting diodes (LEDs) that emit light spanning the entire visible spectrum. Although the tiny full-color LEDs aren't intended for commercial lighting applications, they should be useful in high-resolution microscopy and subwavelength photolithography.

The researchers, Yu-Jung Lu, et al., from National Tsing-Hua University in Hsinchu, Taiwan, have published their study on the nano-LEDs in a recent issue of *Applied Physics Letters*.

The new nano-LEDs have a unique structure that consists of 40-nm-thick nanodisks sandwiched between two layers of nanorods, resulting in a nanodisk-in-nanorod geometry. The nanodisks are made of indium gallium nitride (InGaN), a semiconducting material that is widely used in LEDs and solar cells, while the nanorods are made of gallium nitride (GaN). However, InGaN LEDs capable of emitting light of the entire visible spectrum have not been achieved until now.

"The InGaN/GaN nanodisk/nanorod structure is similar to a well-known quantum well structure, but in a reduced dimensionality (reduction in lateral sizes)," coauthor Shangjr Gwo, a physics professor at National Tsing-Hua University, told *PhysOrg.com*. "The InGaN nanodisks sandwiched between the p- and n-GaN regions act as the full-color visible-light emitters when electrons and holes are injected across the p-n junction at a forward bias voltage. The electroluminescent light comes from the electron-hole recombination within the InGaN nanodisks."

As the researchers explained, the key to achieving full-color LEDs was overcoming large lattice strains, which degrade long-wavelength emissions. The InGaN/GaN nanorod system resolves this issue due to the strain relaxation in the nanostructured geometry.

The researchers hope that these full-color nano-LEDs can be used in high-resolution imaging techniques that can resolve ultrasmall subwavelength features of objects. To do this, these techniques must overcome the diffraction limit, which is a fundamental limit on imaging resolution caused by the spreading out - or "diffraction" - of waves. Imaging techniques can get around this limit by using evanescent waves, which reveal information on objects' subwavelength features, but also decay exponentially away from the object. Due to the short range of the evanescent waves, imaging techniques that detect them are based on near-field optics.

One of these techniques is scanning near-field optical microscopy (SNOM), which uses a tiny probe to generate and retrieve evanescent waves. One of the biggest challenges in SNOM is getting a light source that is small and versatile enough to work on this probe, and that's where the new nano-LEDs come in. While previous research has demonstrated the advantages of using nano-LEDs on the probes, this is the first time that a nano-LED

with a full-color range has been available.

"For microscopy, we can use the nano-LED as a localized excitation light source at a chosen wavelength to selectively excite specific fluorescent molecules," Lu said.

In their study, the researchers experimentally demonstrated using the nanodisk-in-nanorod LEDs for subwavelength photolithography, in which light is used to create a pattern on a light-sensitive material. They predict that, by fabricating the nano-LEDs onto the SNOM probe tips, they could achieve better spatial control for future subwavelength photolithography.

"For the applications of photolithography, the freedom of using nano-LEDs at any wavelength broadens the choice of photoresist and allows for the control of their photo-response," Lu said.

More information: Yu-Jung Lu, et al. "Single InGaN nanodisk light emitting diodes as full-color subwavelength light sources." *Applied Physics Letters*. DOI: 10.1063/1.3597211