Researchers tunnel to a new light source

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With concerns over moving to a clean energy platform worldwide with electric vehicles and renewables, wasted energy is a factor as important as the amount of green energy produced. Thus, solid-state lighting based upon light-emitting diodes (LEDs) is touted as a solution. However, LEDs struggle to deliver high brightness for the shorter-wavelength end of lighting needs. And emitted short wavelengths facilitate white light through known phosphor downconverters.

In *Light: Science & Applications*, Ohio State University researchers and scientists at Wright State University and the Naval Research Laboratory describe a promising new semiconductor LED made with GaN-based materials that could boost wall socket efficiency by reducing energy losses and self-heating.

If this new technology can be harnessed for high light output, the breakthrough could enhance LED solid-state lighting without a significant change to existing LED manufacturing facilities. The new LEDs could provide more light with less voltage and resistance than conventional GaN LEDs, thereby boosting the overall lumens per watt output and avoiding the efficiency droop that plagues high-brightness LEDs.

One way the team has overcome this problem is by completely removing all p-type doping in gallium nitride, which historically is difficult to dope and leads to a high series resistance. The key to the team's discovery is the ability to create "holes" for radiative recombination with electrons by quantum-mechanical tunneling, rather than via p-doping. The tunneling occurs by the Zener mechanism, delivering the holes to the zone of recombination, mitigating the need for clumsy p-type ohmic contacts and resistive p-type semiconductor injectors.

The researchers made their discovery while advancing resonant tunneling diodes (RTD) in the gallium nitride system for the Office of Naval Research under program manager Dr. Paul Maki. As reported in the August 2016 issue of *Applied Physics Letters*, their effort also established a stable GaN-based RTD platform for high microwave power generation and potentially terahertz sources.

The fundamental science behind this advancement is the use of the extremely high electric fields induced by the polarization effects within wurtzite GaN-based heterostructures. These high fields allow the new device not only to inject electrons across a classic RTD double-barrier structure in the conduction band, but also simultaneously to inject holes by Zener tunneling across the GaN band gap into the valence band. Thus, the new LED uses only n-type doping, but includes bipolar tunneling charges to create the new LED light source.

Pursuing commercialization, the team is working to balance the injected electron and hole ratio to create and therefore deliver up to one emitted photon for each injected electron.

More information: Near-UV electroluminescence in unipolar-doped, bipolar-tunneling (UDBT) GaN/AlN heterostructures, *Light: Science & Applications* (2017). DOI: 10.1038/lsa.2017.150 , www.nature-lsa.cn:8080/cms/acc … s/AAP-lsa2017150.pdf

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