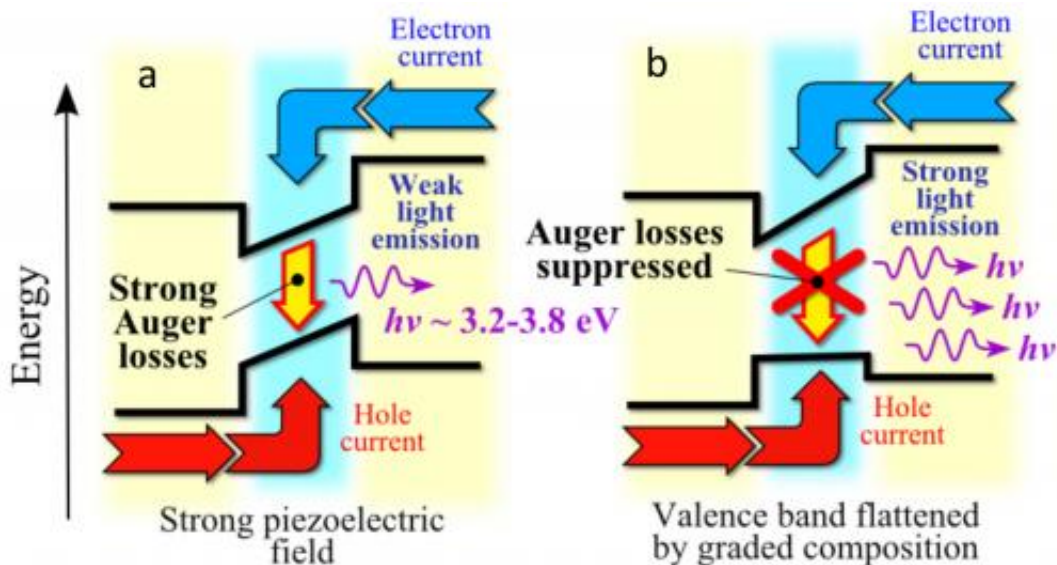


A roadmap to efficient green-blue-ultraviolet light-emitting diodes

February 20 2014, by Donna Mckinney



This is a schematic description of processes responsible for light emitting diode (LED) operation. The thick black lines show the energy band diagram of the conventional (a) and proposed (b) LEDs based on GaN/AlN QWs. In the conventional GaN/AlN QW LEDs the polarization field in the GaN layer enhances strongly the rate of the nonradiative Auger processes leading to reduction of the photoluminescence quantum yield and, consequently, to the "droop" effect with increase of the electrical current. In the proposed LEDs (b) the electric field acting on holes in the QW is compensated by a gradual composition variation of the variable-gap GaAlN alloy resulting in a flat valence band potential. The Auger processes in these QWs are completely suppressed and no droop effect is expected to be seen in such LEDs. Credit: U.S. Naval Research Laboratory

(Phys.org) —Scientists at the U.S. Naval Research Laboratory (NRL) have suggested a method that could significantly increase the efficiency of green-blue-ultraviolet light-emitting diodes based on GaInN/GaN, AlGaIn/GaN, and AlInN/GaN quantum wells. Their approach could enable advances in solid state lighting and the creation of low threshold lasers and high power light emitting diodes (LEDs). Their research is published in the January 25 and November 26, 2013 issues of *Applied Physics Letters*.

Epitaxial perfection in the growth of quantum wells has been the key to achieving light emitting and laser diodes of superior power, efficiency, and performance. Ternary group-III nitrides LEDs based on GaInN/GaN, AlGaIn/GaN, and AlInN/GaN quantum wells now find widespread application in energy-efficient as well as decorative [solid-state lighting](#). But their use in high-power lighting applications is currently hindered by a significant loss in efficiency even at modest electrical currents. Indeed, the quantum efficiency of the LEDs peaks at relatively low currents—a few tens of amperes per square centimeter—and then steadily drops, by almost half, as the current increases. This "droop" in the efficiency is observed in the visible, blue, as well as ultraviolet spectral regions.

Scientists at NRL's Center for Computational Materials Science, in collaboration with researchers at the Technion, Israel, and Ioffe Physical-Technical Institute, Russia, have created computational models showing that the observed droop effect arises from non-radiative Auger recombination of the injected carriers. The rate of the Auger recombination is proportional to the cube of the carrier concentration. As a result, the nonradiative Auger decay rate grows rapidly with current density, quenching the generation of light.

To suppress these non-radiative Auger processes one needs to create quantum wells with a soft confinement potential. Dr. Alexander Efros, a

senior researcher in NRL's Materials Science and Technology Division, previously showed theoretically that a softened electrostatic potential prevents carriers from acquiring the momentum necessary for nonradiative Auger processes, and thus suppresses the Auger decay rate. This concept was patented by NRL in March 2013. The latest calculations by the NRL-Technion-Ioffe research team demonstrate that softening the confinement potential—by varying the alloy composition along the growth direction—also completely suppresses the piezoelectric field that normally enhances nonradiative Auger processes in GaN/AlN QWs. The calculations show that the droop effect in such [quantum wells](#) can be significantly or even completely suppressed.

In addition to Dr. Efros at NRL, the members of the research team include Roman Vaxenburg and Efrat Lifshitz from the Israel Institute of Technology, Haifa, Israel, and Anna Rodina from the Ioffe Physical-Technical Institute, St. Petersburg, Russia.

Provided by Naval Research Laboratory

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