2005

ILLUMINATING IDEAS

Innovations in Solid-State Lighting

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Lighting the Way to Energy Savings

In the next few decades, general illumination technology will undergo a remarkable transformation through improvements in solid-state lighting. No other single lighting technology offers as much potential to conserve electricity, and at the same time, enhance the quality of our building environments.

However, major research challenges must be addressed before the full promise of solid-state lighting is realized. In partnership with industry leaders, research organizations, academic institutions, and national laboratories, the U.S. Department of Energy is working to accelerate technology developments that will profoundly change the future of lighting. These collaborative, cost-shared efforts will ultimately deliver substantial energy savings for all lighting users and position U.S. companies for technology leadership in global markets for new products, systems, and services.

Photos provided by (left to right): Cree, General Electric, Lumileds Lighting, Universal Display

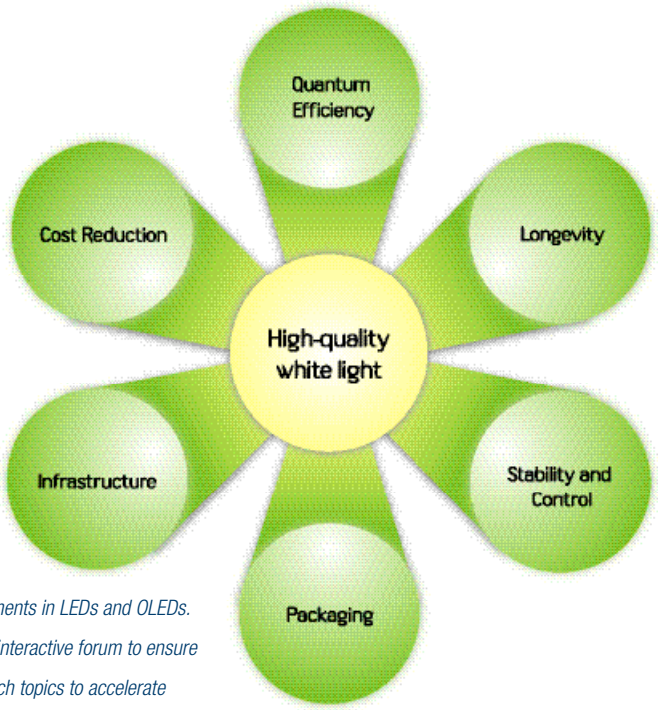
Developments in Solid-State Lighting

Breakthroughs in light emitting diode (LED) and organic light emitting diode (OLED) technology are catalyzing development of energy-efficient solid-state lighting (SSL). Once used only for indicator lights, SSL technology is now found in a variety of specialty applications, including automobile brake lights, traffic signals, exit signs, and flashlights. Research to achieve further technology advances is under way, driving toward development of efficient, full-spectrum, white-light SSL sources that will replace low-efficiency incandescent and fluorescent lamps used for general illumination.

The U.S. Department of Energy (DOE) has invested in SSL technology research since 2000. In this short time frame, DOE researchers have made dramatic progress, achieving several world records.

- Cree Santa Barbara Technology Center's advances in chip technology enabled the demonstration of white LEDs with record efficacies as high as 74 lumens per watt–on par with fluorescent lighting systems and more than four times as efficient as incandescent sources.
- General Electric Global Research eclipsed its own record with the development of a practical-sized OLED light panel that produces 1200 lumens of white light with an efficacy of 15 lumens per watt–on par with today's incandescent sources.
- Lumileds Lighting demonstrated the use of semiconductor nanoparticles as luminescent down-converting materials for white LEDs, producing record conversion yields up to 76 percent.
- Universal Display Corporation developed a low-voltage, high-efficiency white phosphorescent OLED that achieved a record 20 lumens per watt.

The Department supports research and development in six key areas: quantum efficiency, lifetime, sustainability and control, packaging, infrastructure, and cost reduction. Advances in these areas will result in SSL technologies that compete in the general illumination market and deliver significant energy savings.



Through a series of interactive workshops, DOE and its SSL partners have developed an extensive research agenda targeting technology improvements in LEDs and OLEDs. These ongoing workshops provide an interactive forum to ensure that DOE funds the appropriate research topics to accelerate development of efficient, full-spectrum, white-light SSL sources.

Sample Projects

The following sample projects highlight the progress of activities directed at improving the efficiency, longevity, manufacturability, and at decreasing the cost of SSL technology. For more information on each project, see the DOE SSL Project Portfolio at *www.netl.doe.gov/ssl*.

Cermet Inc.: Phosphor-Free Solid-State Lighting Sources

Cermet's work focuses on growing conventional materials on novel substrates with less internal strain. The goal is to implement large-area zinc oxide fluorescent substrate technology and leading edge lattice-matched nitride epitaxy technology to overcome substrate, epitaxy, and device limitations. Through this work, Cermet and collaborators at the Georgia Institute of Technology will bring several innovations to the marketplace, including lattice matched, low defect density nitride emitter structures; white-light emission via a self-fluorescing mechanism in the ZnO substrate; and the ability to adjust the color content of the light emission.

Cree Santa Barbara Technology Center: High-Efficiency LED Lamp for Solid-State Lighting

Cree SBTC is developing LED chip and package technology that will significantly reduce the cost while improving the performance of high-efficiency LED lamps. The research team will combine innovative approaches in GaInN/SiC-based materials technology, LED device fabrication, and solid-state lamp packaging. Together, the improvements will allow the delivery of more light per unit area of LED chip, driving down overall lamp costs.

Los Alamos National Laboratory: Material and Device Designs for Practical Organic Lighting

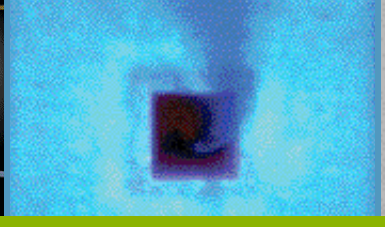
The LANL team is focused on key materials challenges for OLED use in general illumination applications. Their work will advance physical and chemical understanding of how materials-related phenomena can be altered to make very high-efficiency, low-voltage, stable, inexpensive, and reliable devices. The team's theory, fabrication, and measurement approach will optimize understanding of four essential material and device elements: 1) charge injection, 2) carrier mobility, 3) organic/organic heterojunctions, and 4) exciton processes.

OSRAM Opto Semiconductors: Polymer OLED White-Light Development Program

The OSRAM-OS team will develop, fabricate, and fully characterize a 12" x 20" OLED white-light prototype. This advanced white-light prototype will be based on multiple, discrete 2" x 3" white-light devices fabricated on glass substrates. Ultimately, OSRAM-OS expects to produce a color-balanced OLED white-light source with luminous efficacy of 20 lumens per watt at 800 cd/m^2, and achieve an operating half-life of 3,000 hours.

Pacific Northwest National Laboratory: Novel Organic Molecules for High-Efficiency Blue Organic ElectroLuminescence

A PNNL team is exploring the use of state-of-the-art phosphorescent organic light emitters to dramatically increase the power efficiency of blue OLEDs by incorporating them in novel, electron transporting host layers. An alternative way to achieve blue-shifted emissions is to replace the nitrogen heteroatoms with phosphors, which enables the bandgap to increase without eliminating the aromatic backbone of the molecule. These materials are excellent hosts for high-efficiency blue phosphors, as well as longer wavelength OLEDs.




Photos provided by (left to right): Cermet Inc., Los Alamos National Laboratory, OSRAM, Pacific Northwest National Laboratory, University of California Santa Barbara, Sandia National Laboratory/Lumileds Lighting, Technologies and Devices International, Inc.

Sandia National Laboratory: Development of Photonic-Crystal LEDs for Solid-State Lighting

Sandia is teaming with Lumileds Lighting and the University of New Mexico to double the external quantum efficiency of InGaN LEDs. The research team is developing two-dimensional photonic crystal lattices for improving the efficiency of blue LEDs based on InGaN emissive layers. Photonic crystals employ diffractive effects to couple out light that is otherwise lost. The team is investigating two approaches to improving efficiency–radiative efficiency and extraction efficiency.

Technologies and Devices International, Inc.: Novel Low-Cost Technology for Solid-State Lighting

TDI's objective is to demonstrate an alternative cost-effective epitaxial technology for GaN-based LEDs. The proposed technical approach is based on advanced hydride vapor phase epitaxy developed at TDI. Novel low-cost fabrication technology for high-efficiency white-light LEDs will speed up penetration of SSL into the general illumination market.

Universal Display: Novel High Performance OLED Sources (Phase 2)

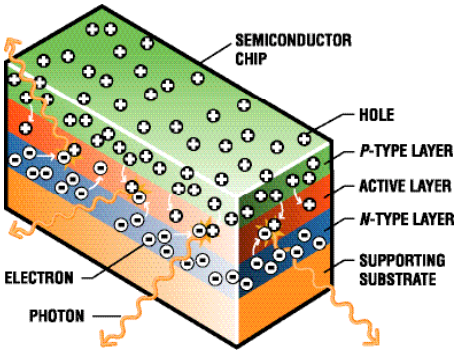
Universal Display and partners at Princeton University and the University of Southern California are building on their successful demonstration of phosphorescent OLED (PHOLED™) technology and pursuing novel approaches to further increase the efficiency of broadband white-light generation. In Phase 2, the team will demonstrate white OLEDs with greater than 20 lumens per watt efficiency at 800 cd/m^2, and deliver 6" x 6" prototype lighting panels.

University of California Santa Barbara: Surface Plasmon Enhanced Phosphorescent Organic Light Emitting Diodes

The UCSB team is exploring novel radiative decay control techniques to harness the energy of triplet excitons. The team is systematically researching ways to blend chromophores and different metal nanostructures to achieve better charge efficiencies and longer device lifetimes.

Efficient Production of Light

When efficiency goals are met, SSL will produce light with less heat than any other source. At the heart of an SSL device is a sandwich of semi-conductor layers built on a substrate. Electrons released from the negative n-type layer combine with holes from the positive p-type layer. These electron-hole pairs recombine in the active layer to produce photons.



An LED is a very small (dot-sized) electrical device that produces light through the semi-conducting properties of its metal alloys. An OLED is a surface-shaped device, similar to an LED, composed of small molecules or polymers that emit light.

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

To Participate in DOE Solid-State Lighting R&D

Does your company, research organization, or university have a promising solid-state lighting technology that will save energy? If so, your research and development efforts may be eligible for funding of up to 80%. To learn more, visit **www.netl.doe.gov/ssl**

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