

## Solid-State Lighting Patents Resulting from DOE-Funded Projects

As of January 2015, 96 solid-state lighting (SSL) patents have been awarded to research projects funded by the U.S. Department of Energy. Since December 2000, when DOE began funding SSL research projects, a total of 247 patent applications have been submitted, ranging from large businesses (79) and small businesses (90) to universities (66) and national laboratories (12).

DOE tracks three types of patent applications. A brief overview and the superscript used to identify each application type follows:

- <sup>NP</sup> U.S. Nonprovisional Patents:** the standard U.S. patent application. Nonprovisional applications are examined by a patent examiner and may be issued as a patent if all requirements for patentability are met.<sup>1</sup>
- <sup>P</sup> U.S. Provisional Patents:** a lower-cost patent application filing option in the U.S. used to establish an early effective filing date in a later-filed nonprovisional patent application. An applicant who files a provisional application must file a corresponding nonprovisional application for patent during the 12-month pendency period in order to benefit.<sup>2</sup>
- <sup>PCT</sup> International Patents:** an international patent application under the Patent Cooperation Treaty (PCT), by which applicants can simultaneously seek protection for intellectual property in 148 countries around the world, including the U.S.<sup>3</sup>

Each patent application has a unique application number used to track progress until a patent is awarded. Patent application titles may not be unique, and often we see the same title for multiple patent applications. For this reason, duplicate titles may be listed in the table below, but each instance corresponds to a unique patent application. Provisional patents are only tracked until the nonprovisional patent is filed, at which point they are superseded to avoid double counting. If a nonprovisional U.S. patent and an international patent are linked (i.e., one is a continuation of the other), the title is listed once but designated with both <sup>NP</sup> and <sup>PCT</sup>. In instances where the patent information is protected, the patent is listed by application type but no title is provided.

Primary Research Organization	Titles of Patent Applications (bold indicates nonprovisional patent granted) <sup>NP</sup> = U.S. Nonprovisional <sup>P</sup> = U.S. Provisional <sup>PCT</sup> = International	
<b>Agiltron</b>	<ul style="list-style-type: none"> <li>• <b>Optoelectronic Device With Nanoparticle Embedded Hole Injection/Transport Layer<sup>NP</sup></b></li> </ul>	<ul style="list-style-type: none"> <li>• One provisional patent application filed<sup>P</sup></li> </ul>
<b>Applied Materials, Inc.</b>	<ul style="list-style-type: none"> <li>• <b>Methods For Improved Growth of Group III Nitride Buffer Layers<sup>NP, PCT</sup></b></li> <li>• <b>Method and Apparatus For Inducing Turbulent Flow of a Processing Chamber Cleaning Gas<sup>NP</sup></b></li> </ul>	<ul style="list-style-type: none"> <li>• Methods For Improved Growth of Group III Nitride Semiconductors<sup>NP</sup></li> <li>• Multiple Complementary Gas Distribution Assemblies<sup>NP</sup></li> </ul>
<b>Arizona State University</b>	<ul style="list-style-type: none"> <li>• Iridium Complexes Demonstrating Broadband Emission Through Controlled Geometric Distortion and Applications Thereof<sup>NP</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Metal Compounds and Methods and Uses Thereof<sup>PCT</sup></li> <li>• Two provisional patent applications filed<sup>P</sup></li> </ul>
<b>Arkema, Inc.</b>	<ul style="list-style-type: none"> <li>• OLED Substrate Consisting of Transparent Conductive Oxide (TCO) and Anti-Iridescent Undercoat<sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Chemical Vapor Deposition Using N,O Polydentate Ligand Complexes of Metals<sup>NP, PCT</sup></li> </ul>
<b>Boston University</b>	<ul style="list-style-type: none"> <li>• <b>Optical Devices Featuring Textured Semiconductor Layers<sup>NP, PCT</sup></b></li> <li>• <b>Optical Devices Featuring Textured Semiconductor Layers<sup>NP</sup></b></li> </ul>	<ul style="list-style-type: none"> <li>• <b>Optical Devices Featuring Textured Semiconductor Layers<sup>NP</sup></b></li> </ul>

1 For more information on nonprovisional patents, see: <http://www.uspto.gov/patents/resources/types/utility.jsp#heading-1>

2 For more information on provisional patents, see: <http://www.uspto.gov/patents/resources/types/provapp.jsp>

3 For more information on PCT and international patents, see: <http://www.wipo.int/pct/en/> or <http://www.uspto.gov/patents/process/file/efs/guidance/indexing-pct-new-appl.pdf>

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Cree, Inc.	<ul style="list-style-type: none"> <li>• Expandable LED Array Interconnect<sup>NP</sup></li> <li>• LED Package Element With Internal Meniscus for Bubble-Free Lens Placement<sup>NP</sup></li> <li>• LED Structure with Enhanced Mirror Reflectivity<sup>NP, PCT</sup></li> <li>• Light Emitting Diode With High Aspect Ratio Submicron Roughness for Light Extraction and Methods of Forming<sup>NP</sup></li> <li>• Light Emitting Diode With Porous SiC Substrate and Method for Fabricating<sup>NP, PCT</sup></li> </ul> <ul style="list-style-type: none"> <li>• Ultra-Thin Ohmic Contacts for P-Type Nitride Light Emitting Devices<sup>NP</sup></li> <li>• Ultra-Thin Ohmic Contacts for P-Type Nitride Light Emitting Devices<sup>NP</sup></li> <li>• Ultra-Thin Ohmic Contacts for P-Type Nitride Light Emitting Devices and Methods of Forming<sup>PCT</sup></li> <li>• High Reflectivity Mirrors and Method for Making Same<sup>NP, PCT</sup></li> </ul>	
Crystal IS, Inc.	<ul style="list-style-type: none"> <li>• Growth of Large Aluminum Nitride Single Crystals With Thermal-Gradient Control<sup>NP, PCT</sup></li> </ul>	
Dow Corning	<ul style="list-style-type: none"> <li>• Four patent applications filed</li> </ul>	
Eastman Kodak	<ul style="list-style-type: none"> <li>• Device Containing Non-Blinking Quantum Dots<sup>NP, PCT</sup></li> <li>• Doped Nanoparticle-Based Semiconductor Junction<sup>NP, PCT</sup></li> <li>• Ex-Situ Doped Semiconductor Transport Layer<sup>NP, PCT</sup></li> <li>• Light-Emitting Nanocomposite Particles<sup>NP, PCT</sup></li> </ul> <ul style="list-style-type: none"> <li>• Method of making highly-confined semiconductor nanocrystals<sup>NP</sup></li> <li>• Highly Confined Semiconductor Nanocrystals<sup>NP, PCT</sup></li> <li>• Making Colloidal Ternary Nanocrystals<sup>NP</sup></li> </ul>	
Eaton Corporation	<ul style="list-style-type: none"> <li>• One provisional patent application<sup>P</sup></li> </ul>	
Fairfield Crystal Technology	<ul style="list-style-type: none"> <li>• Method and Apparatus for Aluminum Nitride Monocrystal Boule Growth<sup>NP</sup></li> </ul>	
GE Global Research	<ul style="list-style-type: none"> <li>• Blue-Green and Green Phosphors for Lighting Applications<sup>NP</sup></li> <li>• Electrodes Mitigating Effects of Defects In Organic Electronic Devices<sup>NP</sup></li> <li>• Light-Emitting Device With Organic Electroluminescent Material and Photoluminescent Materials<sup>NP</sup></li> <li>• Lighting System with Heat Distribution Face Plate<sup>NP, PCT</sup></li> <li>• Lighting System with Thermal Management System<sup>NP, PCT</sup></li> <li>• Lighting System with Thermal Management System Having Point Contact Synthetic Jets<sup>NP, PCT</sup></li> <li>• Luminaire for Light Extraction From a Flat Light Source<sup>NP</sup></li> </ul> <ul style="list-style-type: none"> <li>• Mechanically Flexible Organic Electroluminescent Device With Directional Light Emission<sup>NP, PCT</sup></li> <li>• OLED Area Illumination Source<sup>NP</sup></li> <li>• Organic Electroluminescent Devices and Method for Improving Energy Efficiency and Optical Stability Thereof<sup>NP</sup></li> <li>• Organic Electroluminescent Devices Having Improved Light Extraction<sup>NP, PCT</sup></li> <li>• Series Connected OLED Structure and Fabrication Method<sup>NP</sup></li> <li>• Hybrid Electroluminescent Devices<sup>NP</sup></li> <li>• Materials for Optoelectronic Devices<sup>NP, PCT</sup></li> <li>• Eight other patent applications filed</li> </ul>	
GE Lighting Solutions, LLC	<ul style="list-style-type: none"> <li>• Novel Green Emitting Phosphors and Blends Thereof<sup>NP</sup></li> <li>• Phosphor Suspended In Silicone, Molded/Formed and Used In A Remote Phosphor Configuration<sup>NP, PCT</sup></li> </ul> <ul style="list-style-type: none"> <li>• One provisional patent application filed<sup>P</sup></li> </ul>	
General Electric Company	<ul style="list-style-type: none"> <li>• Alkaline and Alkaline Earth Metal Phosphate Halides and Phosphors<sup>NP</sup></li> <li>• Coated Phosphors, Methods of Making Them, and Articles Comprising the Same<sup>NP, PCT</sup></li> <li>• Color Stable Manganese-Doped Phosphors<sup>NP, PCT</sup></li> </ul> <ul style="list-style-type: none"> <li>• Color Stable Phosphors<sup>NP, PCT</sup></li> <li>• Kimzeyite Garnet Phosphors<sup>NP</sup></li> <li>• Alkaline Earth Borate Phosphors<sup>NP</sup></li> </ul>	
Georgia Tech Research Corporation	<ul style="list-style-type: none"> <li>• One patent application filed</li> </ul>	
International Technology Exchange	<ul style="list-style-type: none"> <li>• One patent application filed</li> </ul>	
KLA-Tencor	<ul style="list-style-type: none"> <li>• Scattered Light Separation<sup>NP</sup></li> </ul> <ul style="list-style-type: none"> <li>• Substrate Inspection<sup>NP, PCT</sup></li> </ul>	
Lawrence Berkeley National Laboratory	<ul style="list-style-type: none"> <li>• Carbon Nanotube Polymer Composition and Devices<sup>NP</sup></li> </ul> <ul style="list-style-type: none"> <li>• Organic Light Emitting Diodes With Structured Electrodes<sup>NP</sup></li> </ul>	
Lehigh University	<ul style="list-style-type: none"> <li>• Gallium Nitride-Based Device and Method<sup>NP</sup></li> <li>• Staggered Composition Quantum Well Method and Device<sup>NP, PCT</sup></li> </ul> <ul style="list-style-type: none"> <li>• Staggered Composition Quantum Well Method and Device<sup>NP</sup></li> </ul>	

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Light Prescriptions Innovators	<ul style="list-style-type: none"> <li>Optical Device for LED-Based Lamp<sup>NP, PCT</sup></li> <li>Optical Manifold<sup>NP</sup></li> <li>Optical Manifold for Light-Emitting Diodes<sup>NP, PCT</sup></li> <li>Optical Manifold for Light-Emitting Diodes<sup>NP</sup></li> </ul>	<ul style="list-style-type: none"> <li>Wide Band Dichroic-Filter Design for LED-Phosphor Beam Combining<sup>NP</sup></li> <li>Three patent applications filed</li> </ul>
Lightscape Materials Inc.	<ul style="list-style-type: none"> <li>Carbonitride Based Phosphors and Light Emitting Devices Using The Same<sup>NP, PCT</sup></li> <li>Oxycarbonitride Phosphors and Light Emitting Devices Using The Same<sup>NP, PCT</sup></li> <li>Oxycarbonitride Phosphors and Light Emitting Devices Using The Same<sup>NP</sup></li> </ul>	<ul style="list-style-type: none"> <li>Silicon Carbonitride Based Phosphors and Lighting Devices Using The Same<sup>NP, PCT</sup></li> <li>Oxycarbonitride Phosphors and Light Emitting Devices Using The Same<sup>NP</sup></li> </ul>
Maxdem Incorporated	<ul style="list-style-type: none"> <li>Polymer Matrix Electroluminescent Materials and Devices<sup>NP, PCT</sup></li> </ul>	
Moser Baer India Ltd.	<ul style="list-style-type: none"> <li>Method of Manufacturing Organic Lighting Device<sup>NP</sup></li> </ul>	
Nanosys	<ul style="list-style-type: none"> <li>Nanocrystal Doped Matrices<sup>NP, PCT</sup></li> </ul>	
National Renewable Energy Laboratory	<ul style="list-style-type: none"> <li>Lattice-Mismatched GaInP LED Devices and Methods of Fabricating Same<sup>NP</sup></li> <li>High Bandgap III-V Alloys for High Efficiency Optoelectronics<sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>Solid State Lighting Devices and Methods with Rotary Cooling Structures<sup>NP</sup></li> </ul>
OSRAM Opto Semiconductors	<ul style="list-style-type: none"> <li>Integrated Fuses for OLED Lighting Device<sup>NP</sup></li> <li>Novel Method To Generate High Efficient Devices, Which Emit High Quality Light for Illumination<sup>NP</sup></li> <li>Thermal Trim for a Luminaire<sup>NP</sup></li> </ul>	<ul style="list-style-type: none"> <li>Polymer and Small Molecule Based Hybrid Light Source<sup>NP</sup></li> <li>OLEDs With Phosphors<sup>NP</sup></li> <li>One provisional patent application filed<sup>P</sup></li> </ul>
Osram Sylvania Inc.	<ul style="list-style-type: none"> <li>Ceiling Mounted Luminaire<sup>NP</sup></li> <li>Interior Frame for Solid State Light Source Luminaire<sup>NP</sup></li> <li>Thermal Trim for a Luminaire<sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>Apparatus Incorporating an Optically Transmitting Circuit Board<sup>NP</sup></li> <li>Arrangement of Solid State Light Sources and Lamp Using Same<sup>NP</sup></li> <li>One patent application filed</li> </ul>
Pacific Northwest National Laboratory	<ul style="list-style-type: none"> <li>OLED Devices<sup>NP</sup></li> <li>Organic Materials With Phosphine Sulphide Moieties Having Tunable Electric and Electroluminescent Properties<sup>NP</sup></li> </ul>	<ul style="list-style-type: none"> <li>Organic Materials With Tunable Electric and Electroluminescent Properties<sup>NP, PCT</sup></li> </ul>
Philips Electronics North America	<ul style="list-style-type: none"> <li>Four patent applications filed</li> </ul>	
Philips Lumileds Lighting, LLC	<ul style="list-style-type: none"> <li>Zener Diode Protection Network In Submount for LEDs Connected In Series<sup>NP</sup></li> <li>LED Module With High Index Lens<sup>NP</sup></li> </ul>	<ul style="list-style-type: none"> <li>Molded Lens Incorporating a Window Element<sup>NP</sup></li> <li>One provisional patent application filed<sup>P</sup></li> </ul>
PhosphorTech Corporation	<ul style="list-style-type: none"> <li>Light Emitting Device Having Selenium-Based Fluorescent Phosphor<sup>NP</sup></li> <li>Light Emitting Device Having Silicate Fluorescent Phosphor<sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>Light Emitting Device Having Sulfoselenide Fluorescent Phosphor<sup>NP, PCT</sup></li> <li>Light Emitting Device Having Thio-Selenide Fluorescent Phosphor<sup>NP</sup></li> </ul>
Purdue University	<ul style="list-style-type: none"> <li>Metalized Silicon Substrate for Indium Gallium Nitride Light-Emitting Diode<sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>Process for Fabricating III-Nitride Based Nanopyramid LEDs Directly On A Metalized Silicon Substrate<sup>NP</sup></li> </ul>
Rensselaer Polytechnic Institute	<ul style="list-style-type: none"> <li>Free-Standing Mounted Light Emitting Diodes for General Lighting<sup>NP</sup></li> </ul>	<ul style="list-style-type: none"> <li>Method of Fabricating An Ohmic Contact to N-Type Gallium Nitride<sup>NP</sup></li> </ul>
Research Triangle Institute	<ul style="list-style-type: none"> <li>Reflective Nanofiber Lighting Devices<sup>NP, PCT</sup></li> <li>Color Tunable Lighting Devices and Methods for Tuning Color Output of Lighting Devices<sup>NP</sup></li> <li>Lighting Devices with Color-Tuning Materials and Methods for Tuning Color Output of Lighting Devices<sup>NP, PCT</sup></li> <li>Long-Pass Optical Filter Made From Nanofibers<sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>Photoluminescent Nanofiber Composites, Methods and Fabrication, and Related Lighting Devices<sup>NP</sup></li> <li>Stimulated Lighting Devices<sup>PCT</sup></li> </ul>
Sandia National Laboratory	<ul style="list-style-type: none"> <li>Cantilever Epitaxial Process<sup>NP</sup></li> </ul>	<ul style="list-style-type: none"> <li>Nanowire-Templated Lateral Epitaxial Growth of Non-Polar Group III Nitrides<sup>NP</sup></li> </ul>

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Sinmat, Inc.	<ul style="list-style-type: none"> <li>• <b>High Light Extraction Efficiency Solid State Light Sources</b><sup>NP</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Chemical Mechanical Fabrication for Forming Tilted Surface Features<sup>NP</sup></li> </ul>
Sora, Inc.	<ul style="list-style-type: none"> <li>• Process for Large-Scale Ammonothermal Manufacturing of Semipolar Gallium Nitride Boules<sup>NP</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Two patent applications filed</li> </ul>
State University of New York, Buffalo	<ul style="list-style-type: none"> <li>• Two patent applications filed</li> </ul>	
Universal Display Corporation	<ul style="list-style-type: none"> <li>• <b>Binuclear Compounds</b><sup>NP, PCT</sup></li> <li>• <b>Intermediate Connector for Stacked Organic Light Emitting Devices</b><sup>NP</sup></li> <li>• <b>Organic Light Emitting Device Architecture for Reducing The Number of Organic Materials</b><sup>NP</sup></li> <li>• <b>Organic Light Emitting Device Structure for Obtaining Chromaticity Stability</b><sup>NP</sup></li> <li>• <b>Organic Light Emitting Device Structure for Obtaining Chromaticity Stability</b><sup>NP</sup></li> <li>• <b>Organic Light Emitting Device With Conducting Cover</b><sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>• <b>Organic Light-Emitting Devices for Illumination</b><sup>NP, PCT</sup></li> <li>• <b>White Phosphorescent Organic Light Emitting Devices</b><sup>NP</sup></li> <li>• General Bus Line Design Rules for Large-Area OLED Lighting<sup>NP</sup></li> <li>• Light Extraction Blocks for Thin Form Factor OLED Lighting With Improved Power Efficacy<sup>NP</sup></li> <li>• Novel Host Compounds for Red Phosphorescent OLEDs<sup>NP</sup></li> <li>• Stacked OLEDs With A Reflective Conductive Layer<sup>NP</sup></li> <li>• Organic Light Emitting Device Architecture<sup>PCT</sup></li> </ul>
University of California, San Diego	<ul style="list-style-type: none"> <li>• <b>Rare-Earth Activated Aluminum Nitride Powders and Method of Making</b><sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Two patent applications filed</li> </ul>
University of California, Santa Barbara	<ul style="list-style-type: none"> <li>• <b>Enhancing Performance Characteristics of Organic Semiconducting Films By Improved Solution Processing</b><sup>NP</sup></li> <li>• <b>Horizontal Emitting, Vertical Emitting, Beam Shaped, Distributed Feedback (DFB) Lasers By Growth Over A Patterned Substrate</b><sup>NP, PCT</sup></li> <li>• <b>Plasmon Assisted Enhancement of Organic Optoelectronic Devices</b><sup>NP, PCT</sup></li> <li>• <b>Single or Multi-Color High Efficiency Light Emitting Diode (LED) by Growth Over A Patterned Substrate</b><sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Light Emitting Devices with Embedded Void-Gap Structures through Bonding of Structured Materials on Active Devices<sup>NP</sup></li> <li>• Nanowire-Polymer Composite Electrodes<sup>NP</sup></li> <li>• Optoelectronic Devices With Embedded Void Structures<sup>NP</sup></li> <li>• Selective Dry Etching of N-Face (Al,In,Ga)N Heterostructures<sup>NP</sup></li> <li>• Semiconductor Micro-Cavity Light Emitting Diode<sup>NP, PCT</sup></li> <li>• Silicone Resin Encapsulants for Light Emitting Diodes<sup>NP</sup></li> <li>• Two patent applications filed</li> </ul>
University of Florida Research Foundation	<ul style="list-style-type: none"> <li>• Stable and All Solution Processable Quantum Dot Light-Emitting Diodes<sup>NP</sup></li> </ul>	
University of Michigan	<ul style="list-style-type: none"> <li>• <b>Gas Cushion Control of OVJP Print Head Position</b><sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>• <b>Ultrabright Fluorescent OLEDs Using Triplet Sinks</b><sup>NP, PCT</sup></li> </ul>
University of North Texas	<ul style="list-style-type: none"> <li>• Organic Light-Emitting Diodes From Homoleptic Square Planar Complexes<sup>PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Two provisional patent applications filed<sup>P</sup></li> </ul>
University of Southern California	<ul style="list-style-type: none"> <li>• <b>Fluorescent Filtered Electrophosphorescence</b><sup>NP, PCT</sup></li> <li>• <b>Fluorescent Filtered Electrophosphorescence</b><sup>NP</sup></li> <li>• <b>OLEDs Utilizing Macrocyclic Ligand Systems</b><sup>NP</sup></li> <li>• <b>Organic Light Emitting Device Having Multiple Separate Emissive Layers</b><sup>NP, PCT</sup></li> <li>• <b>Organic Vapor Jet Deposition Using An Exhaust</b><sup>NP, PCT</sup></li> <li>• <b>Phenyl and Fluorenyl Substituted Phenyl-Pyrazole Complexes of Ir</b><sup>NP</sup></li> <li>• <b>Stable Blue Phosphorescent Organic Light Emitting Devices</b><sup>NP, PCT</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Low Index Grids (LIG) To Increase Outcoupled Light From Top Or Transparent OLED<sup>NP</sup></li> <li>• Luminescent Compounds with Carbene Ligands<sup>PCT</sup></li> <li>• Materials and Architectures for Efficient Harvesting of Singlet and Triplet Excitons for White Light Emitting OLEDs<sup>NP</sup></li> <li>• OLED with Improved Light Outcoupling<sup>PCT</sup></li> <li>• Two patent applications filed</li> </ul>
WhiteOptics, LLC	<ul style="list-style-type: none"> <li>• One patent application filed</li> </ul>	
Yale University	<ul style="list-style-type: none"> <li>• Conductivity Based Selective Etch for GaN Devices and Applications Thereof<sup>PCT</sup></li> </ul>	