2014 Nobel Prize in Physics
Isamu Akasaki
Hiroshi Amano
Shuji Nakamura
1. The Story Behind Shuji Nakamura's Invention of Blue LEDs

This year’s Nobel Prize in Physics was shared between three Japanese blue LED inventors Isamu Akasaki, Hiroshi Amano and Shuji Nakamura. The three inventors were recognized for their achievements in the highly energy efficient blue LED, which led to the emergence of white light.

Red and green LEDs have been around for nearly half a century, but developments in blue LEDs were obstructed by technological difficulties. Without blue lights, white lamps could not be made. Many scientists and industry experts tried to manufacture blue LEDs, but no one succeeded for 30 years.

It was not until early 1990s that Akasaki and Amano developed Gallium Nitride (GaN) LED at Nagoya University, while Nakamura developed the LED during his employment in Nichia Chemical (Nichia) at the time. Their inventions revolutionized lighting in the 21st century, by...
replacing the chemically hazardous incandescent lamps with LED lamps. The Nobel Prize has been awarded to the three scientists just 20 years after the three developed blue GaN LED.

Blue GaN LED inventor Professor Hiroshi Amano of Nagoya University (left) with Aledia CEO Giorgio Anania (right). (Photo Credit: Aledia)

Akasaki is currently a professor at Meijo University, Nagoya, Japan and Nagoya University, Japan, while Amano is a professor at Nagoya University, Japan. Nakamura, who has been coined as the “Father of GaN Blue LED”, is now a professor at University of California, Santa Barbara, U.S. The 8 million Swedish Krona (US $1.11 million) Nobel Prize money will be split among the three laureates.

“I am very honored to receive the Nobel Prize from The Royal Swedish Academy of Science for my invention of the blue LED,” said Nakamura. “It is very satisfying to see that my dream of LED lighting has become a reality. I hope that energy-efficient LED light bulbs will help reduce energy use and lower the cost of lighting worldwide.”
Shuji Nakamura was elated to learn he had won the Nobel Prize Award. He later went on to found LED startup company Soraa. (Photo Credit: Soraa)

Events leading to Shuji Nakamura and Nichia’s lawsuit
Nakamura has been a pioneer in changing old practices in Japan’s R&D industry. Commercialization of blue LED happened in a relatively short period of time from 1993 to 1994. After graduating from University of Tokushima, Nakamura began working at the Tokushima-based Nichia. It was during his time at Nichia that he developed blue GaN LEDs using the more cost effective doping method (low-temperature heating). Nakamura threatened his supervisors that he would resign if they did not provide him with resources to develop GaN, which is the key material to developing blue LEDs. After successfully manufacturing blue LEDs in 1994, Nichia went on to develop commercialized green LEDs the following year, and laser diodes (LD) in 1999. After Nakamura left Nichia Chemical, the University of California, Santa Barbara hired him as a professor.

Nichia was able to acquire many key LED patents and sell high quality LEDs because of scientists, such as Nakamura. The scientist shook the Japanese technology industry in 2001, when he filed a lawsuit against Nichia seeking US $180 million in compensation for his LED invention. The company was reported to have only given Nakamura US $180 for his blue GaN LED invention when he left the company in the 1990s. According to a Wall Street Journal report, foreign researchers and inventors even coined him as “Slave Nakamura” when they learned how little the devoted salaryman was earning in Nichia. Despite using Nichia resources to develop blue GaN LEDs, Nakamura believed he was the rightful patent holder and inventor, and should be compensated for his work.

The lawsuit created quite an uproar that year. The Tokyo District Court ruled Nichia should pay at least 60.4 billion Japanese Yen (US $560 million) to Nakamura for his contributions in blue LEDs, but lowered the compensation sum to 20 billion Japanese Yen after taking into consideration Nakamura had only asked for that much in the complaint. The court estimated Nichia earned a profit totaling 120 billion Japanese Yen from the blue LED patent invention alone, and initially based the compensation sum on Nakamura’s contributions reaching 50
percent of company profits. Nichia appealed to the initial ruling and the lawsuit dragged on for years before the two parties finally agreed to settle for 844 million Japanese Yen compensation on Jan. 11, 2005. The lawsuit set a precedent in Japan for employees suing employers.

Shuji Nakamura chats with fellow attendees during LEDforum 2011. Nakamura was a guest speaker at the annual event hosted by LEDinside that year. (LEDinside)

Nakamura’s departure from Japan enables LED technology to blossom in foreign markets

Many LED manufacturers were stunned when Nakamura developed the first blue LED because Nichia’s LEDs were reliability and robustness was far superior. It took other LED manufacturers several years before they could catch up with Nichia’s white LED and blue LED achievements. Even today, Nichia’s LEDs remain the top choice for LED backlight applications in Apple’s iPad, iPhone and high-end Android smartphone displays. Nichia still offers better quality LEDs for backlight applications, compared to other manufacturers, whether it’s the LED size, brightness, luminous efficacy, or reliability wise.

Nakamura’s decision to pursue an American dream and leave Japan was not just an academic decision, but also had to do with his complicated feelings towards former employer Nichia. The two sides had very different perspectives on the blue LED patent lawsuit outcome. Nakamura “indirectly” assisted U.S. manufacturer Cree in developing high-power LED, and later formed an academic partnership with Korean LED manufacturer Seoul Semiconductor. Some of Seoul Semiconductor’s new products were based on Nakamura’s research results, which is especially ironic for Nichia.

If Nichia valued Nakamura’s research results, hard work, and gave him the payment he deserved, the company could have maintained its leadership position in the LED industry. For R&D staff in the scientific industry, it is important for their expertise to be valued. If most companies treated R&D staff in the same way as Nichia did to Nakamura, than it is probably not surprising that employees may decide to leave or even take legal action against the company.
2. Edison Opto Launches 0.8 W Filament to Mimic Incandescent Lamps

With the rise of global environmental awareness, incandescent bulb is banned in various countries successively which drives traditional lighting manufacturers to transform into LED lighting. Aiming for this opportunity, the Taiwanese LED packaging manufacturer, Edison Opto, branches out into filament market and releases 0.8W LED filament. Used in 4W bulb, the LED bulb can replace 40W incandescent bulb, bringing the advantages (energy saving and high efficiency) of LED into full play. Edison Opto can assist traditional incandescent bulb manufacturer in entering LED lighting market.

Edison Opto's new LED filaments bring a visual experience which is similar to traditional incandescent lamps.

Edison’s 0.8W filament uses packaging technology and serial LED chips to achieve 360° (omnidirectional) light distribution. With excellent light quality, the filament brings a whole new visual experience which is unlike traditional LED. As a result of using copper substrate as lead frame, the filament has better heat dissipation and higher reliability performance. Furthermore, the luminous efficacy of Edison filament can reach 125lm/W (under 2700K, CRI > 80) which is well-matched with sapphire substrate. With the advantages of high lm/$ and superior luminous efficiency, Edison’s 0.8W filament helps customers to achieve the same lighting effect and longer lifespan (up to 25000 hours) with lower prices.

In most of the lighting market, general consumers are still accustomed to using traditional light sources. The LED filament bulbs can substitute incandescent bulbs directly and create a nostalgic lighting space. Edison’s 0.8W filament is under mass production and can be ordered now.
3. LG Innotek Introduces UV LEDs with World-class Power Performance

LG Innotek, a global components manufacturer, today announced that the company succeeded in the mass-production of the world’s highest power 275nm UV (ultraviolet) LEDs. Such success is expected to trigger an explosion of UV LEDs for purification and sterilization applications.

Mass-Production of the new UV-LED commences in October for 275nm UV-C LEDs for air purification and water sterilization applications
LG Innotek reported that it mass-produced 275nm UV-C LEDs which emit in the “C” region (200 ~ 280 nm) of the UV spectrum for sterilization and began supply to a global consumer electronics company this month.
LG Innotek’s UV-C LED products will be included in the consumer electronics lineup such as air cleaner, water purifier, toothbrush sterilizer, and other sanitary products. A test performed by Korea Conformity Laboratories (KCL) found that this product removes 99.99% of E. Coli, salmonella, and other germs within 5-liters of water contained in 25 minutes; this is as effective as the existing mercury UV lamp.

UV-C LED has drawn much attention as an attractive alternative to the mercury UV lamp due to its numerous advantages including high efficiency, long life, ultra-compact size, and eco-friendliness. However, until recently, only sample quantities of UV-C LEDs were circulated in the industry because of limitations in power and emission wavelengths. LG Innotek has developed a proprietary LED optimization technology to improve the optical power of a UV-C LED chip up to 10 mW at 100mA, the world’s highest. It has also improved optical efficiency by 15% compared to the mercury lamp, consuming less electrical power.
The company’s UV-C LED measures 6.8mm x 6.8mm and has a depth of only 1.35mm. It has been tested to provide 10,000 hours of operation life time, which is 1.5 times longer than the mercury lamp. Moreover, its “instant-on” nature means it does not need any warm-up time to achieve start the purification/sterilization process, unlike the mercury lamp that could require over 10-minutes to reach its full power.
Unlike UV lamps, this LED product does not use potentially hazardous heavy metals such as mercury. It offers high safety, high durability, and water proof performance. It achieved the IPX7 level of Ingress Protection rating, meaning its performance is unchanged even after being submerged in water at 1 m depth for 30 minutes.

LG Innotek said “Since our last April’s announcement of the mass production of UV-A (365~400nm) LED, which is used in industrial areas, we have further advanced our UV LED technology by the mass-production UV-C LED for purification/sterilization applications. LG Innotek offers the best UV LED chip, package, and module solutions for our customers”

According to “UV LEDs report” by Yole Development, a France-based market research company, the UV LED market is forecast to grow from 100 million dollars in 2014 year to 270 million dollars in 2017 (43% annually). Korean market research company, SNE Research, also expects the share of LEDs in the UV light source market to increase from 11% in 2012 to 62% in 2018.

Oct. 08, 2014

4. Osram Announces New Soleriq S 19 Versions with Two Different CRIs

Osram Opto Semiconductors launches new product versions of the Soleriq S 19 with two different color rendering indexes (CRI). As with all versions of the S 19 the new LEDs can be used in all applications where high lumen packages from a compact light source are needed. They are especially suited for professional downlight and spotlight applications, for example in shop and office environments.

Osram's updated Soleriq S 19 LEDs offer CRI 80 or 90 and between 2,000 lm an 5,000 lm.
The new Osram Soleriq S 19 LEDs are available with color rendering indexes (CRI) 80 and 90. There are two CRI 80 versions with brightness values of 2000 and 5000 lumens (lm) and three CRI 90 LEDs with 2000, 3000 and 5000 lm. An S 19 LED with CRI 80 and 3000 lm has already been launched. As with all Soleriq S 19 LEDs the new products are based on the standards defined by Zhaga and have a light-emitting surface with a diameter of 19 mm. With the new product versions Osram Opto Semiconductors now offers one LED family (Soleriq) with similar package size and various lumen and CRI options, so customers neither have to change optic and reflector design nor connectors when upgrading their product range. Furthermore, the LEDs can be driven in low-current mode to achieve even higher efficacies or in high-current mode to achieve high light output. In this way, different requirements of luminaires can be met with the same set of optics and holders.

When installed in lamps and luminaires, the new Soleriq S 19 LEDs can be used for professional downlight applications in offices and shops but also for hospitality lighting. They offer a high flexibility in this context: If customers want to implement lighting solutions in rooms with lower ceilings, e. g. offices, they can choose the S 19 version with 2000 lm. If rooms with high ceilings are to be illuminated (e. g. shopping malls), an LED with a high lumen package is the perfect choice.

All Soleriq LEDs are based on Chip-on-Board technology. This technology guarantees a uniform color and light appearance thanks to the close arrangement of the chips beneath a conversion layer. The LEDs are very simple to work with as they are screwed to the heat sink with a connector. Then the connecting wires just need to be inserted into the connectors provided and fixed in place. There is no longer any need for SMT (Surface Mount Technology) soldering. Accessories such as connectors, optics and drivers tailored to the Soleriq family can be obtained by the Osram partner network LED Light for you (LLFY). Customers can either go to the LLFY website or use the free “LLFY Selector” app so they can find the perfect products on the move.

Sept. 30, 2014

5. Cree Sets Efficiency Standard with Commercially Available 150 Lumens-Per-Watt Troffer

New ZRHE LED Troffer Delivers Unprecedented 70 Percent Energy Savings

DURHAM, NC -- Cree, Inc. (Nasdaq: CREE) introduces the ZR High-Efficacy (HE) LED troffer, an industry-leading commercial specification-grade troffer designed to reduce energy consumption by 70 percent when compared to traditional fluorescent troffers, enabling greater design freedom for customers looking to achieve LEED certification. Cree’s vertical integration and LED lighting system development expertise has outpaced the industry once again by bringing a commercially available 150-lumens-per-watt LED troffer to market. With a 100,000-hour lifetime—twice as long as comparable LED troffers—and an industry-leading, 10-year limited warranty, the Cree® ZRHE LED troffer is the ideal replacement for
healthcare, petroleum, commercial building and other applications demanding extreme reliability and long product lifetime. The ZRHE LED troffer features Cree TrueWhite® Technology and delivers 4000 lumens of the industry’s best color quality in both 2’ x 2’ and 2’ x 4’ configurations. With 0-10V dimming capabilities standard, the ZRHE Series LED troffer can deliver even greater energy savings and help meet emerging energy codes for new and retrofit installations that require 24/7 operation.

“The Cree ZRHE LED troffer pushes the limits of LED technology, redefining the standard for the commercial specification-grade market by delivering the breakthrough combination of energy savings, superior color quality and reduced maintenance costs,” said Norbert Hiller, Cree executive vice president, lighting. “Cree’s latest innovation delivers benefits customers have not had before and eliminates the need for compromised fluorescent alternatives.”
Journals

1. Synthesis and photoluminescent properties of Sr2Si5N8:Eu2+ red phosphors for white light-emitting diodes

By: Chang, Liu; Bi, Zhang; Luyuan, Hao; Xin, Xu

Journal of Rare Earths, Volume 32, Issue 8, Pages 691-695
DOI: 10.1016/S1002-0721(14)60127-7

Highly efficient Sr2Si5N8:Eu2+ red emitting phosphor was successfully synthesized by a cost-effective direct silicon nitridation and gas-redn. method. The effects of synthesis parameters, including reaction temp., heating rate and gas species, on the crystal structure and photoluminescence of the prepd. phosphors were studied. Single-phase Sr2Si5N8:Eu2+ phosphor was obtained at 1500 °C with a heating rate of 300 °C/h under NH3-1 vol.%CH4 atmosphere using starting silicon and oxide powders. Silicon powder and high heating rate favored the achievement of the pure Sr2Si5N8 phase. Under near-UV to blue light excitation, the obtained Sr2Si5N8:Eu2+ phosphor showed a board red emission band centered at about 625 nm, which agreed well with the phosphors prepd. by the conventional solid-state reaction. The possible reaction mechanism was also proposed based on the exptl. observations.


By: Liu, Yan; Liu, Guixia; Wang, Jinxian; Dong, Xiangting; Yu, Wensheng

Inorganic Chemistry, Pages Ahead of Print, Journal, 2014
DOI: 10.1021/ic501284y

Tm3+, Dy3+, and Eu3+ codoped NaGd(WO4)2 phosphors were prepd. by a facile hydrothermal process; they were characterized by X-ray diffraction (XRD), field emission scanning electron microscope (FESEM), energy-dispersive X-ray spectrometer (EDS), photoluminescence spectra, and fluorescence lifetime. The results show that the novel octahedral microcrystals with a mean side length of 2 μm are obtained. Under the excitation of UV, individual RE3+ ion (Tm3+, Dy3+, and Eu3+) activated NaGd(WO4)2 phosphors exhibit excellent emission properties in their resp. regions. Moreover, when codoping Dy3+ and Eu3+/Tm3+ in the single component, the energy migration from Dy3+ to Eu3+ has been demonstrated to be a resonant type via a dipole-quadrupole mechanism as well as that from Tm3+ to Dy3+ ions, of which the crit. distance (RDy-Eu) is calcld. to be 11.08 Å. More significantly, in the Tm3+, Dy3+, and Eu3+ tridoped NaGd(WO4)2 phosphors, the energy migration of Tm3+-Dy3+-Eu3+, utilized for sensitizing Eu3+ ions besides compensating the red component at low Eu3+ doping concn., has been discussed first. In addn., under 365 nm near-UV radiation (nUV), the color-tunable emissions in octahedral NaGd(WO4)2 microcrystals are realized by giving abundant blue,
green, white, yellow, and red emissions, esp. warm white emission, and could be favorable candidates in full-color phosphors for nUV-LEDs.

3. White light emission from NaLa(PO3)4: Dy3+ single-phase phosphors for light-emitting diodes

By: Liu, Fengxin; Liu, Qihui; Fang, Yongzheng; Zhang, Na; Yang, Bobo; Zhao, Guoying

DOI:10.1016/j.ceramint.2014.09.078

White light emission phosphors NaLa(PO3)4: Dy3+ were synthesized by a solid-state method. XRD anal. confirmed that all the Dy3+ doped phosphors are single phase. The photoluminescence excitation and emission spectra, concn. effect, decay property, and CIE coordinates were investigated. Strong excitation peaks of NaLa(PO3)4: Dy3+ were found around 350-400 nm, which matched well with those of the near-UV LED chips. Under 350 nm excitation the NaLa(PO3)4: Dy3+ exhibits intense white emission by combining the two emission peaks at 485 nm and 571 nm, attributed to the characteristic 4F9/2-6H15/2 and 4F9/2-6H13/2 transitions of Dy3+. The optimum doped concn. of Dy3+ ions is around 6 mol% and the crit. transfer distance of Dy3+ is calcd. as 15.4 Å. In addn., the CIE chromaticity coordinates of NaLa(PO3)4: Dy3+ phosphors are (0.2923, 0.3359). The results indicate that the NaLa(PO3)4: Dy3+ phosphors have great potential as a single-component white-light-emitting phosphor for UV-light-emitting diodes.

4. A novel blue-emitting phosphor Gd4.67Si3O13:Bi3+ for near-UV LEDs

By: Zhou, Hongpeng; Jiang, Mingsong; Jin, Ye

RSC Advances, Volume 4, Issue 86, Pages45786-45790
Journal; Online Computer File, 2014
DOI:10.1039/C4RA08716J

A novel blue-emitting phosphor Gd4.67Si3O13:Bi3+ has been synthesized by a conventional high-temp. solid-state method. X-ray diffraction, and photoluminescence spectra were used to characterize the as-synthesized phosphor. Upon 370 nm excitation, the Gd4.67Si3O13:Bi3+ phosphor exhibits a broad emission band centered at 455 nm. Monitoring the 455 nm emission, the Gd4.67Si3O13:Bi3+ phosphor shows an intense broad absorption band ranging from 200 to 400 nm. The energy transfer mechanism between Bi3+ ions has been discussed, which is demonstrated to be dipole-dipole interaction. The crit. concn. is 3 mol% and the crit. distance is found to be 25.7 Å. The thermal stability and the CIE coordinates are also investigated in this work. The CIE coordinates of the Gd4.67Si3O13:Bi3+ phosphor upon 370 nm excitation are (0.141, 0.096). All the results indicate that the blue-emitting phosphor Gd4.67Si3O13:Bi3+ has potential applications for white LEDs.
Patents

1. Neodymium-and-ytterbium-codoped rare earth titanate up-conversion luminescent material, method for preparing thereof and organic light-emitting diode

By: Zhou, Mingjie; Wang, Ping; Chen, Jixing; Huang, Hui


The title neodymium-and-ytterbium-codoped rare earth titanate up-conversion luminescent material has a chem. formula of Me$_2$Ti$_2$O$_7$:xNd$_{3+}$,yYb$_{3+}$, wherein x is 0.01-0.08, y is 0-0.1, and Me is one of La, Gd and Lu. In photoluminescence spectrum of the material, excitation wavelength of the material is 980nm, the material forms luminescent peak by transition radiation of Nd$_{3+}$ ion from $^3P_0$ to $^3H_4$ in the region of wavelength of 485nm, and can be used as blue light-emitting material. The invention also provides a method for prepg. the material and an org. light-emitting diode using the material.

![Graph](image)

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2. Ce:YAG microcrystalline glass for white light LED
Ce:YAG microcryst. glass capable of implementing yellow light emission under the condition of blue light excitation, and a prepn. method therefor. Ce:YAG fluorescence microcrystals are inlaid uniformly in an oxide glass substrate in the microcryst. glass. The microcryst. glass comprises the glass substrate components (mol.%): 0-10 SiO₂, 0-40 CeO₂, 20-60 TeO₂, 0-25 B₂O₃, 0-15 P₂O₅, 0-10 Al₂O₃, 0-20 Ac₂O, 0-20 ZnO, 0-15 BaO, 0-20 Sb₂O₃, 0-20 La₂O₃, 0-10 Bi₂O₃, Ae being selected from Li, Na or K, and the content of Ce:YAG microcrystals is 1-15 wt.% of the oxide glass substrate. The microcryst. glass can emit yellow light under the excitation of blue light, and the yellow light and the blue light are combined to generate intense white light, and therefore, the microcryst. glass can be used for construction of a white light LED excited by a blue light chip.

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3. Barium europium strontium nitride silicate based phosphor and light emitting device
A phosphor and a light emitting device are provided. The phosphor comprises a compn.
having a formula of \((\text{Ba}_a\text{Sr}_{1-a})_2\text{Z}_8\text{Si}_5\text{O}_n\text{N}_m\text{Eu}_z\), \(0.03<a<0.75\), \(0<b<1\), \(7<n<9\), and \(0.03<z<0.3\).

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### Priority Application

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4. Preparation of near ultraviolet-excited rare earth doped borate phosphor matrix and phosphor

By: Chen, Chao; Zheng, Jianghui; Cai, Lihan; Ying, Lili; Chen, Wenzhi; Chen, Rong; Fan, Baodian

Assignee: Xiamen University, Peop. Rep. China

The invention discloses a method for prep. near UV-excited rare earth doped borate phosphor matrix and phosphor. The borate phosphor has a general formula of \(\text{NaBaBO}_3:x\text{Re}, y\text{M}\) (or \(\text{BaNaBO}_3:x\text{Re}, y\text{M}\)), where \(\text{NaBaBO}_3\) (or \(\text{BaNaBO}_3\)) is a luminescent matrix; \(\text{Re}\) is a doping rare earth light emission center, and is at least one of europium, dysprosium, thulium, terbium, samarium, praseodymium, erbium or manganese, and \(0<x\leq0.20\); and \(\text{M}\) is an auxiliary doping element, and is at least one or more of lithium, sodium, potassium, silicon, boron, aluminum, gallium and indium, and \(0<y\leq0.20\). The prep. method includes weighing barium carbonate, boric acid, sodium carbonate, a rare earth oxide and a compd. of \(\text{M}\), and grinding and mixing; heating and calcimining in atm. of hydrogen gas, nitrogen gas, carbon monoxide or a mixt. thereof; and grinding. By doping different rare earth elements in the matrix, a fluorescent material with strong emission in various spectral regions under the excitation of near UV can be obtained. The prep. method is simple, easy to operate, clean, and low in cost. The phosphor can be applied in a violet-excited tricolor white LED phosphor, a down-conversion solar cell phosphor and a variety of display devices, and can also be used as a near violet-excited down-conversion fluorescent material in an agricultural film for promoting the growth of crops.

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5. Core-shell phosphor containing semiconductor nanoparticle cores, and light source and LED light source using the same as wavelength converter

By: Tanaka, Hidenori; Inoue, Kenji; Matsumoto, Kazuaki; Uematsu, Taro; Yasutake, Ryota; Kuwahata, Susumu

Assignee: Kaneka Corp., Japan; Osaka University

The title phosphor comprises ≥1 semiconductor nanoparticle cores, and a shell covering the cores and/or filling gaps between the cores. The semiconductor nanoparticle cores comprise Group 11 element-Group 13 element sulfides or Zn-Group 11 element-Group 13 element sulfides. Preferably, the shell comprises SiO₂, ZnS, or silicone. The phosphors do not inhibit curing of a packaging resin, e.g., silicone, for an LED element.

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