

June 11-13  
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# COMPOUNDSEMI ONLINE

## Pioneering the Blue Spectrum

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Blue spectrum solid state light emitting diodes (LEDs) and laser diodes (LDs) made of Group III nitride materials, are revolutionizing the world of lighting and optical storage. The history of their evolution is the classic "20 year overnight success" story. The visionaries who pioneered the commercial applications kept chipping away and, finally, in 2003 the blue spectrum industry is tapping the Mother Lode.

The R&D roots go back much further, long before most people realize. Back in the mid 1950s, Herbert Paul Maruska's group at RCA labs in the USA appear to be the first recorded demonstration that the wide bandgap compound semiconductor base material, Gallium Nitride (GaN), indeed had the capability of producing especially bright devices in the blue spectrum. Like so many scientific discoveries, progress was slow but sure. It wasn't until the mid 1990s that a breakthrough artist named Shuji Nakamura moved blue spectrum device science out of the R&D realms and into mainstream consumer applications.

"Shuji" (as he has come to be known to his industry colleagues and friends) was fittingly honored at "The Celebration of the Blues" highlight evening during the *Blue 2003: Behind the Hot Apps*. Shuji Nakamura will go down in history as the most colorful hero in the brightest, most promising semiconductor sector since the dawn of the microprocessor.

There are many blue spectrum pioneers who deserve to be honored, all of whom will eventually be publicly recognized by *CompoundSemi* and their stories made public and archived on *CompoundSemi Online*. Two in particular are unable to attend Blue 2003 to receive Pioneer awards, but their contributions are so important, they simply have to be noted from the outset.

The first is George Craford, the lead catalyst at Lumileds Lighting, whose vision began at Hewlett Packard Labs in Palo Alto, California USA. The second is Max Yoder of the US DoD's Office of Naval Research who saw to it the field was adequately funded and that the research community was finally expanded to include Eastern European scientists. The story of these technology champions will be reserved for next time.

The five people personally in attendance and honored at Blue 2003, collectively tell the rest of the compelling Blue Spectrum success story.

Thus, we present an overview of the first five chapters of our story, which will soon appear in its entirety over *CompoundSemi Online*.



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# COMPOUNDSEMI *ONLINE*

*Chapter 1 – The first CompoundSemi Pioneer Award for 2003 goes to...*

## **Michael Shur**

Our story begins with Michael Shur who was in the initial wave of Russian scientists to immigrate to the USA to further his considerations of the fundamental nature of this remarkable compound semi material called GaN. GaN is the common denominator behind today's hot applications. Educated in Russia, Michael Shur, Ph.D., holds the Patricia W. and C. Sheldon Roberts Professorship in the Electrical Computer and Systems Engineering Department at Rensselaer Polytechnic Institute (RPI) in Troy, New York USA.

Michael's original contribution was "solid fact," revealing the appropriateness and realities of applying GaN solutions to a myriad of solid state lighting challenges. His *Introduction to Solid State Lighting*, co-authored by Arturas Zukauskas and Remis Gaska, is now *THE* textbook in this quickly evolving, truly revolutionary field.

Michael Shur's many achievements are a reminder of the incredible scientific strides that were being made on both sides of the old Iron Curtain during the so-called "Cold War," which compelled scientists to work in parallel... but in isolation from one another. Those days are finally behind us. No individual, no country, need work in isolation every again.

***Michael Shur represents the power and potential of international synergy.***

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# COMPOUNDSEMI ONLINE

Chapter 2 – The second CompoundSemi Pioneer Award for 2003 goes to...

## Norman Schumaker

Many brilliant ideas started at Bell Labs, including the epitaxial tool that would eventually lead the compound semi industry toward the growth process that has come to make GaN devices the commercial success they are today. EMCORE began as a Bell Labs spinout. The original founder of EMCORE was Norman S. Schumaker, Ph.D., who named the company for what it really was—and what MOCVD (Metal-Organic Chemical Vapor Deposition) platforms are today: The Core of Electronic Materials (EMCORE).

All of today's blue spectrum GaN-based LEDs and LDs are created in epitaxial processing tools, like Emcore's cleverly named GaNzilla. Emcore was founded by visualizing what would be required to create reproducible, high brightness photonic devices and outstanding electronic devices in volume quantities. Others were quick to follow Emcore's lead, with most focusing on customized R&D tools, but two companies in particular—Emcore and Aixtron—created progressively larger scale MOCVD reactors that eventually facilitated the mass production of LED and LD devices in all colors of the visible and UV. If it weren't for the fierce competition between these two companies, the blue spectrum field wouldn't be where it is today. We'd probably have to wait yet another 20 years.

Norm Schumaker is truly a technology champion. He had the vision; he fought the fight. Norm, who retired from Emcore in the 1990s, has recently helped put together a new startup company in Austin, Texas USA to create yet another lynchpin tool. This one is for advanced lithography and it's called Molecular Imprints. Norm's new company's mission is to accomplish what his early stage MOCVD equipment company did 20 years ago... revolutionize the industry. As the latest contribution to the manufacturing fab floor, Molecular Imprint's advanced litho tool promises to help everyone dramatically increase their yields while significantly lowering their cost of manufacturing.

***Norm Schumaker represents the power of reproducibility. Without reliable repeatability, you simply have science. If you have a product people want and need, and you can make it for less than you can sell it, you have the criteria for commercial success.***

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# COMPOUNDSEMI *ONLINE*

*Chapter 3 – The third CompoundSemi Pioneer Award for 2003 goes to...*

## ***The Founders of CREE***

The story never changes. Young scientists go off to college, work together under a brilliant, futurist professor, and they band together to form a promising high tech startup... and live happily every after. That's what happened at CREE, about 20 years ago. A group of brilliant students studied the prospects of a recalcitrant compound semi material, called silicon carbide (SiC), under North Carolina State University's famed Bob Davis. A comfortably close wide bandgap material to GaN, the founders of Cree were able to successfully grow their own material and fashion it into progressively more reliable, reproducible blue spectrum devices.

The first true, commercial blue spectrum LEDs came from Cree in Durham, North Carolina USA, and found their way into soft, cool, pleasing lighting in eye-sensitive interior environments like elevators and the interior of automobiles. While SiC blue spectrum devices continued to get brighter and less expensive, the GaN breakthroughs of Shuji Nakamura changed the scene. At the time of his breakthrough work, Shuji was leading Nichia's development in Anan, Japan. Shuji proved that a layer of GaN on top of a suitable host substrate could help move the blue spectrum from behind the elevator and auto doors into the bright outdoors. About 1994, devices made of SiC on native substrates began to move more heavily towards the robust electronic applications that required materials that could handle especially harsh environments. GaN on SiC, and/or GaN on sapphire soon ruled the blue spectrum.

Cree's founding technical trio: John Edmond, Calvin Carter, and John Palamour, are still together on the front lines at the company they helped found. Cree was the first to focus, concertedly, on commercializing the blue spectrum LEDs and LDs and has grown in size and respect to become one of the most successful companies, and most desirable to work for, in the compound semi industry.

***Cree's founders represent the classic American entrepreneurial 'Dream Team,' proving to us all, once again, that dreams really can come true.***

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# COMPOUNDSEMI *ONLINE*

*Chapter 4 – The fourth CompoundSemi Pioneer Award for 2003 goes to...*

## **Robert V. Steele**

The next recipient of also preceded Shuji in championing the blue spectrum. He was tracking R&D progress and counting blue SiC optoelectronic devices and substrates at companies like Cree and Siemens long before GaN came on the commercial scene. When the GaN breakthroughs by the Nichia team clearly indicated where the higher brightness blue spectrum devices could take the field, he led the charge. Robert Steele, Ph.D., has been with Strategies Unlimited since the mid-1980s and he's seen it all, and reported it all... with tremendous accuracy and sensitivity.

One of the primary reasons that particular market research firm is so highly regarded is because of Bob Steele. As Director of Optoelectronics Programs at Strategies, Bob has pioneered responsible reporting of the evolution of blue spectrum devices. Since 1997 he has provided the annual laser diode market update and forecast for Laser Focus World magazine and the Laser Marketplace Seminar, which are owned and operated by one of the most reputable names in advanced technology publishing: PennWell, which now owns Strategies Unlimited.

Bob has co-authored more than 30 multiclient and single client reports on optoelectronic markets, technology and competition and he has always maintained an unbiased view point and even-handed approach. And the numbers he stands behind prove, year after year, to be accurate and timely. He supervised and co-authored three editions of Strategies Unlimited's periodic report on GaN technology and markets, and four editions of their biannual report on the visible LED market, as well a recent report titled: "Solid-State Lighting: New Growth Opportunities for High Brightness LEDs." He is also the Chair of Strategies in Light, the company's annual industry conference on HB-LEDs.

***Bob Steele represents the importance of patience, accuracy, and objectivity. And he adds that personal touch, which continues to help foster a spirit of inclusiveness, cohesiveness, and cooperation that, distinguishes the international blue spectrum community.***

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# COMPOUNDSEMI *ONLINE*

*Chapter 5 – The fifth and final CompoundSemi Pioneer Award for 2003 goes to...*

## **Shuji Nakamura**

As stated at the beginning of this totally true, very enlightening story, Shuji Nakamura, Ph.D., has become one of the most noteworthy and most colorful technology heroes to hit the high tech world for some time. While he may not have “invented” the LED nor blue spectrum LEDs and LDs as you can see by the stories of his fellow CompoundSemi Pioneers, he certainly made today’s devices possible... and popular. And he did it with a persistent faith in his material of choice—GaN—employing a growth process everyone wanted to emulate.

Imitation is said to be the highest form of flattery, and virtually everyone in today’s solid state blue spectrum community is following the lead Shuji originally established while at Nichia in Anan, Japan. Now, a USA professor of materials and director for the Center for Solid State Lighting and Displays at the University of California Santa Barbara (UCSB) in California, Shuji has achieved what the academic community enjoys calling “a golden sandbox.” In addition to holding the CREE Chair, Shuji was most recently awarded an ERATO grant by the Japan Science and Technology Corporation. This Japanese government grant amounts to approximately \$16 million and is being used to help establish a strong infrastructure of native bulk GaN material, which is deemed key to widespread commercial use of GaN in such devices as semiconductor lasers and electronic transistors.

Shuji believed in GaN from the start, and was attracted to that particular compound combination for the reason so many, especially in Asia, have adopted that material. GaN is one of the most environmentally benign semiconductor materials on earth. While it may be at the heart of disrupting the lighting, storage, and even the electronic industries, it’s looked upon kindly by Mother Nature. No wonder GaN-based blue spectrum devices are “The Mother Lode.”

Shuji is a strong proponent of environmental solutions to the myriad of ills that plague the Earth. The environmental ramifications of moving to new energy sources, like GaN based devices to satisfy the world’s increasing appetite for brighter lights, are incredible and far-reaching. But Shuji’s message is the simple truth all of us need to remember. Work within the laws of Nature—not against them. There’s a reason the blue spectrum is so appealing. It is the color of the sky, the water, the trees, the grass, and the UV spectrum only non-human plants and animals seem to see. *Mother Nature Rules.*

***Shuji Nakamura represents the power of true innovation when it’s combined with a profound respect for the environment. Shuji Nakamura represents a cause Asians traditionally and naturally embrace. Isn’t it time the rest of the world does too?***