building a brighter diode

H igh-brightness LEDs have been making a splash across the visible spectrum for the past few years, but they’re still a long way from realizing their full potential, with solid-state illumination and far-UV devices still under development.

“The vast majority of indium gallium nitride (InGaN) LEDs look very much like the first Nichia devices, which were put on the market nine years ago,” Steve Stockman, manager of InGaN characterization at Lumileds (San Jose, CA), told attendees of the Materials Research Society’s fall meeting (2–6 December; Boston, MA).

The average blue LED emitting at 470 nm has a quantum efficiency of about 25%, he said, noting that most LEDs can handle input power of only about 0.1 W. Using phosphor coatings or mixing LEDs of different wavelengths generates white light at efficiencies of 20 to 30 lm/W. These figures are somewhat better than for incandescent bulbs, but LEDs are two to four orders of magnitude behind incandescent and other lighting technologies in output power, Stockman said. It would take 1000 LEDs to provide light comparable to that of a single mercury lamp, and the cost of providing that light is about 50 cents per lumen. That has to come down, he said, to 1 cent per lumen.

The market for solid-state lighting is still under $100 million, but it’s growing at 50% a year, says Robert Steele, director of optoelectronics at market research firm Strategies Unlimited (Mountain View, CA). LEDs are still too expensive, he says, but with a worldwide general illumination market estimated at $12 billion for lamps alone, LED makers are going to try to usurp the place of incandescent, fluorescent, and halogen bulbs. “That’s the big payoff that everyone sees, but that’s probably at least five to 10 years away,” Steele says.

Lumileds now make LEDs driven by up to 5 W input power, and much of that improvement was due to changes in the design of the device, Stockman said. A major limiting factor is how much powder coatings or mixing LEDs of different wavelengths generates white light at efficiencies of 20 to 30 lm/W. These figures are somewhat better than for incandescent bulbs, but LEDs are two to four orders of magnitude behind incandescent and other lighting technologies in output power, Stockman said. It would take 1000 LEDs to provide light comparable to that of a single mercury lamp, and the cost of providing that light is about 50 cents per lumen. That has to come down, he said, to 1 cent per lumen.

The market for solid-state lighting is still under $100 million, but it’s growing at 50% a year, says Robert Steele, director of optoelectronics at market research firm Strategies Unlimited (Mountain View, CA). LEDs are still too expensive, he says, but with a worldwide general illumination market estimated at $12 billion for lamps alone, LED makers are going to try to usurp the place of incandescent, fluorescent, and halogen bulbs. “That’s the big payoff that everyone sees, but that’s probably at least five to 10 years away,” Steele says.

Lumileds now make LEDs driven by up to 5 W input power, and much of that improvement was due to changes in the design of the device, Stockman said. A major limiting factor is how much powder coatings or mixing LEDs of different wavelengths generates white light at efficiencies of 20 to 30 lm/W. These figures are somewhat better than for incandescent bulbs, but LEDs are two to four orders of magnitude behind incandescent and other lighting technologies in output power, Stockman said. It would take 1000 LEDs to provide light comparable to that of a single mercury lamp, and the cost of providing that light is about 50 cents per lumen. That has to come down, he said, to 1 cent per lumen.

The market for solid-state lighting is still under $100 million, but it’s growing at 50% a year, says Robert Steele, director of optoelectronics at market research firm Strategies Unlimited (Mountain View, CA). LEDs are still too expensive, he says, but with a worldwide general illumination market estimated at $12 billion for lamps alone, LED makers are going to try to usurp the place of incandescent, fluorescent, and halogen bulbs. “That’s the big payoff that everyone sees, but that’s probably at least five to 10 years away,” Steele says.

Lumileds now make LEDs driven by up to 5 W input power, and much of that improvement was due to changes in the design of the device, Stockman said. A major limiting factor is how much powder coatings or mixing LEDs of different wavelengths generates white light at efficiencies of 20 to 30 lm/W. These figures are somewhat better than for incandescent bulbs, but LEDs are two to four orders of magnitude behind incandescent and other lighting technologies in output power, Stockman said. It would take 1000 LEDs to provide light comparable to that of a single mercury lamp, and the cost of providing that light is about 50 cents per lumen. That has to come down, he said, to 1 cent per lumen.

The market for solid-state lighting is still under $100 million, but it’s growing at 50% a year, says Robert Steele, director of optoelectronics at market research firm Strategies Unlimited (Mountain View, CA). LEDs are still too expensive, he says, but with a worldwide general illumination market estimated at $12 billion for lamps alone, LED makers are going to try to usurp the place of incandescent, fluorescent, and halogen bulbs. “That’s the big payoff that everyone sees, but that’s probably at least five to 10 years away,” Steele says.

Lumileds now make LEDs driven by up to 5 W input power, and much of that improvement was due to changes in the design of the device, Stockman said. A major limiting factor is how much powder coatings or mixing LEDs of different wavelengths generates white light at efficiencies of 20 to 30 lm/W. These figures are somewhat better than for incandescent bulbs, but LEDs are two to four orders of magnitude behind incandescent and other lighting technologies in output power, Stockman said. It would take 1000 LEDs to provide light comparable to that of a single mercury lamp, and the cost of providing that light is about 50 cents per lumen. That has to come down, he said, to 1 cent per lumen.

The market for solid-state lighting is still under $100 million, but it’s growing at 50% a year, says Robert Steele, director of optoelectronics at market research firm Strategies Unlimited (Mountain View, CA). LEDs are still too expensive, he says, but with a worldwide general illumination market estimated at $12 billion for lamps alone, LED makers are going to try to usurp the place of incandescent, fluorescent, and halogen bulbs. “That’s the big payoff that everyone sees, but that’s probably at least five to 10 years away,” Steele says.

Lumileds now make LEDs driven by up to 5 W input power, and much of that improvement was due to changes in the design of the device, Stockman said. A major limiting factor is how much powder coatings or mixing LEDs of different wavelengths generates white light at efficiencies of 20 to 30 lm/W. These figures are somewhat better than for incandescent bulbs, but LEDs are two to four orders of magnitude behind incandescent and other lighting technologies in output power, Stockman said. It would take 1000 LEDs to provide light comparable to that of a single mercury lamp, and the cost of providing that light is about 50 cents per lumen. That has to come down, he said, to 1 cent per lumen.

The market for solid-state lighting is still under $100 million, but it’s growing at 50% a year, says Robert Steele, director of optoelectronics at market research firm Strategies Unlimited (Mountain View, CA). LEDs are still too expensive, he says, but with a worldwide general illumination market estimated at $12 billion for lamps alone, LED makers are going to try to usurp the place of incandescent, fluorescent, and halogen bulbs. “That’s the big payoff that everyone sees, but that’s probably at least five to 10 years away,” Steele says.

Lumileds now make LEDs driven by up to 5 W input power, and much of that improvement was due to changes in the design of the device, Stockman said. A major limiting factor is how much powder coatings or mixing LEDs of different wavelengths generates white light at efficiencies of 20 to 30 lm/W. These figures are somewhat better than for incandescent bulbs, but LEDs are two to four orders of magnitude behind incandescent and other lighting technologies in output power, Stockman said. It would take 1000 LEDs to provide light comparable to that of a single mercury lamp, and the cost of providing that light is about 50 cents per lumen. That has to come down, he said, to 1 cent per lumen.

The market for solid-state lighting is still under $100 million, but it’s growing at 50% a year, says Robert Steele, director of optoelectronics at market research firm Strategies Unlimited (Mountain View, CA). LEDs are still too expensive, he says, but with a worldwide general illumination market estimated at $12 billion for lamps alone, LED makers are going to try to usurp the place of incandescent, fluorescent, and halogen bulbs. “That’s the big payoff that everyone sees, but that’s probably at least five to 10 years away,” Steele says.

Lumileds now make LEDs driven by up to 5 W input power, and much of that improvement was due to changes in the design of the device, Stockman said. A major limiting factor is how much powder coatings or mixing LEDs of different wavelengths generates white light at efficiencies of 20 to 30 lm/W. These figures are somewhat better than for incandescent bulbs, but LEDs are two to four orders of magnitude behind incandescent and other lighting technologies in output power, Stockman said. It would take 1000 LEDs to provide light comparable to that of a single mercury lamp, and the cost of providing that light is about 50 cents per lumen. That has to come down, he said, to 1 cent per lumen.

The market for solid-state lighting is still under $100 million, but it’s growing at 50% a year, says Robert Steele, director of optoelectronics at market research firm Strategies Unlimited (Mountain View, CA). LEDs are still too expensive, he says, but with a worldwide general illumination market estimated at $12 billion for lamps alone, LED makers are going to try to usurp the place of incandescent, fluorescent, and halogen bulbs. “That’s the big payoff that everyone sees, but that’s probably at least five to 10 years away,” Steele says.

Lumileds now make LEDs driven by up to 5 W input power, and much of that improvement was due to changes in the design of the device, Stockman said. A major limiting factor is how much powder coatings or mixing LEDs of different wavelengths generates white light at efficiencies of 20 to 30 lm/W. These figures are somewhat better than for incandescent bulbs, but LEDs are two to four orders of magnitude behind incandescent and other lighting technologies in output power, Stockman said. It would take 1000 LEDs to provide light comparable to that of a single mercury lamp, and the cost of providing that light is about 50 cents per lumen. That has to come down, he said, to 1 cent per lumen.
Heat the epoxy (with a glass transition temperature of 120°C) enclosing the LED die can handle. Traditional LEDs use long, thin wires of plated steel, which is a poor thermal conductor. Engineers replaced those with a heat sink made of copper attached to a metal-core PC board, bringing thermal resistance from 200°C/W down to approximately 10°C/W.

They also wanted to use a larger chip that could handle more power, replacing a chip 0.1 to 0.15 mm² with one 1 mm², but that would potentially have made light extraction more difficult. “If there are losses inside the chip, that means the absorption goes way up and extraction efficiency goes way down,” Stockman said. The solution was to use a flip-chip design, bonding the die upside down and replacing the thin metal contact through which photons would have to pass with a thick, silver-based contact that reflects the photons back through the substrate and out the other side. That brought extraction efficiency up to about 50%, Stockman said, and also provided more uniform current injection over the larger active area of the chip.

Another area of interest is UV LEDs. These can be coated with phosphors to produce visible light, and at wavelengths under 300 nm, they are of interest in areas such as biological agent detection and covert communications. Toshio Nishida of NTT Basic Research Laboratories (Kanagawa, Japan) reported on an LED with a transparent substrate that had a maximum output power of 1.5 mW with an injection current of 70 mA under room-temperature, continuous-wave operation.

Aluminum-gallium-nitride (AlGaN) single quantum-well LEDs grown on bulk GaN substrates suffer from the fact that GaN absorbs wavelengths lower than 370 nm. Nishida’s team instead grew an aluminum-nitride homoepitaxial layer, an undoped AlGaN buffer layer, and an AlGaN-based LED structure. The wafer had a transparency of about 90%, doubling the extraction efficiency of a UV LED on a GaN substrate.

Maxim Shatalov of the University of South Carolina (Columbia, South Carolina) has developed an AlGaN LED on a sapphire substrate that produces 3-mW pulsed power at 278 nm. The device has poor electrical performance, he said, operates at cryogenic temperatures, and has external efficiency below 1%, but it has the highest power reported so far and is already suitable for experimenting with what can be done at such a wavelength. —Neil Savage