GLOWING THINGS

Professor Vladimir Bulovic and Ph.D. candidates Seth Coe-Sullivan and Jonathan Steckel broke new ground with their research in **QUANTUM DOT LEDS**, which Bulovic calls "glowing things." Their work will form the basis for a coming generation of electronic displays that promise to offer extraordinary color, low power consumption, and flexible forms not possible with current technology.

Like father, like son, like grandson.

Seth Coe-Sullivan is not only a third-generation electrical engineer. He's also a third-generation entrepreneur. Both his father and grandfather built successful businesses. So when Coe-Sullivan met Vladimir Bulovic in 2000 he immediately recognized a kindred spirit and signed on to be Bulovic's first graduate student at MIT.

A GREEN, GLOWING VIAL

At the time, Bulovic was a rising star in the field of organic light-emitting diodes (OLEDs), which utilize organic compounds that give off light in response to an electrical current. But he also had his eye on something new: During an exploratory visit to MIT in 1999, he had been mesmerized by a green, glowing vial of quantum dots (QDs) he saw sitting on a bench top in chemist Moungi Bawendi's lab. Bawendi was one of the world's foremost authorities on the synthesis of QDs: inorganic, nano-sized semiconductors that luminesce when they're excited by light or an electrical charge. And those green dots in the vial were of a richer, more saturated color than any "glowing thing" Bulovic had ever worked with.

Now, newly appointed to the MIT faculty, Bulovic shared his vision with Coe-Sullivan: build a lab from scratch, do pioneering research at the nexus of electrical engineering and chemistry, and bring their innovations to the huge global market for electronic displays, projected to be $110 billion dollars by 2017.

MAKING A QD SANDWICH

Thus began a close collaboration between Bulovic's lab and Bawendi's. Working side by side for hours on end, Coe-Sullivan and Wing-Keung Woo from the Bawendi group achieved a major breakthrough within 18 months. Overcoming what were thought to be fundamental processing incompatibilities between organic and inorganic materials, they developed a hybrid, nanometer-scale fabrication technique, creating a quantum-dot LED (QLED) that achieved a 25-fold improvement in luminescence efficiency over previous devices.

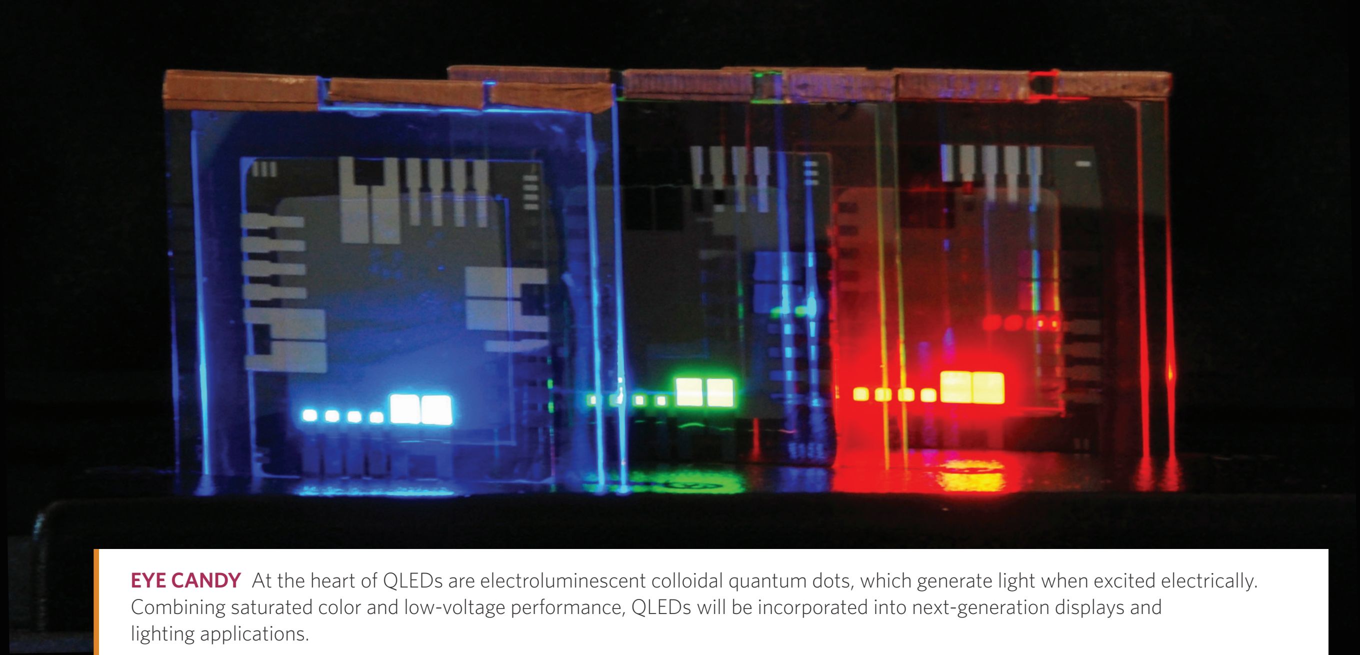
The QLED structure contained a single layer of light-emitting quantum dots, ranging from 3 to 12 nanometers in size, sandwiched between two organic thin films. The paper the team co-authored on this work, which was published in the journal *Nature* in 2002, was a landmark in the field and has been cited nearly a thousand times by other researchers.

COLOR ME BLUE (AND RED AND GREEN)

Bawendi team member Jonathan Steckel cleared the next major hurdle when he figured out the chemistry for making energy-efficient blue QDs, which Coe-Sullivan

KEY INNOVATORS

- VLADIMIR BULOVIC, Professor of Electrical Engineering, head of the Organic and Nanostructural Electronics Laboratory at MIT, and co-founder of QD Vision
- SETH COE-SULLIVAN, PH.D., QD Vision co-founder and Chief Technology Officer
- JONATHAN STECKEL, PH.D., QD Vision co-founder and Director of Materials R&D



EYE CANDY At the heart of QLEDs are electroluminescent colloidal quantum dots, which generate light when excited electrically. Combining saturated color and low-voltage performance, QLEDs will be incorporated into next-generation displays and lighting applications.

successfully incorporated into a QLED device. In 2004, the pair solved another vexing problem: Full-color displays require that each pixel be divided into a red, a blue and a green sub-pixel. Their initial technique for depositing quantum dots—which resembled the act of making a sandwich by evenly spreading a thin layer of jelly across a slice of bread—did not allow for this kind of orderly deposition of different colored sub-pixels.

Coe-Sullivan and Steckel devised a transfer printing method that deposited a solvent mixture, containing dots of one color, onto a rubber stamp that had tiny, premolded ridges. When the solvent evaporated, the dots could be stamped on the surface of the film in orderly rows. Repeating this process with red, green and then blue dots created the required pixel structure.

"IS THERE A COMPANY HERE?"

The team's research was already well along when Bulovic and Coe-Sullivan applied for a Deshpande Center grant. The funding allowed Coe-Sullivan to continue improving the performance and lifetime of the QLEDS. More importantly, he says, "It gave us the time and space to think about the issues around a startup: Is this a technology? Is it intellectual property? Is it ready to be turned into a product and start a company?"

That reflection paid off in 2004 when Coe-Sullivan learned, quite by chance, that a company was interested in licensing one of his key patents. That spurred the team to quickly form a company on paper (which they named QD Vision) and sign an option to license the patent in question from MIT's Technology Licensing Office. Over the next few months, Coe-Sullivan successfully defended his Ph.D. thesis, the team won Series A financing, and QD Vision began its life as an operating company in 2005.

> *"The opportunity to work with Vlad was really compelling. He was a young professor with a lot of exuberance, a vision for the work he wanted to pursue, and a real startup mentality."*
>
> SETH COE-SULLIVAN
> describing his mentor, Vladimir Bulovic

In the years since, QD Vision has rolled out a number of products for the solid-state lighting market, including technology that imparts the warmth of incandescent lighting to far more efficient LED lighting. The QLED innovations that came out of Bulovic's lab are still in the pipeline as the company continues to make advancements in device performance and manufacturability. Once R&D is completed, these devices will form the basis of next-generation electronic displays and solid-state lighting products.