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Light-emitting diode technology and applications: introduction

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Spurred on by the invention of the blue light-emitting diode (LED) a quarter of a century ago, the LED industry has advanced dramatically and has revolutionized the signaling/signage, mobile and flat panel display, and more recently, general lighting markets. Indeed, LEDs now out-surpass in performance all conventional (e.g., incandescent, fluorescent, high-intensity discharge) light sources in general illumination applications. The question arises: what more is to be done? Thus comes the thesis for this special issue on LEDs and applications. From the contributed articles, we learn that LED technology continues to evolve and transform itself not only within the existing applications but is also positioning for brand new applications to come, both of which are highlighted here.

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For the first time, quantum-dot based light-emitting diodes (LEDs) are observed to outperform phosphor-based LEDs for general illumination. Long anticipated, quantum dots (aka semiconductor nanoparticles) have been expected to have an impact on LED applications due to their tuneable emission characteristics and potential for low (back-scattering) loss. However, difficulty in withstanding on-chip LED photo-flux intensity and temperature held back this approach for decades. As we learn in this feature issue, however, innovations related to the passivation of quantum dot materials make this opportunity a reality, with demonstrated spectral luminous efficacies outperforming phosphor-based LEDs, and possibly portending a major disruption in the LED markets for lighting and displays, wherein quantum dots may replace phosphors.

Connectivity is central to the internet and the future of the "Internet of Things" (IoT). Increasing the density and efficacy of viable communication nodes and increasing bandwidth for communication are critical for realizing the IoT vision. Visible light communication (VLC) provides such a platform. From another of the articles contributed to this feature issue, we learn that LED-based VLC can reach data communication rates of 10 Gb/s, approaching the data rates envisioned for 5G.

Micro-LED technology, typically meaning LED chips with footprints of 100 μm × 100 μm or less, is an emerging technology that has relevance for VLC but could also disrupt illumination and displays. A major challenge has been: how to handle and arrange the vast quantity of these devices in order to effect meaningful display and lighting products? Through another of the contributed articles in this feature issue, we learn of an elastomer-based approach for single-head pick-and-place technology that is in principle capable of handling tens of thousands or even hundreds of thousands of devices at a time. This technology has the possibility to revolutionize back-end LED packaging and assembly with so far unimagined implications for illumination and display products.

Augmented/virtual reality and smart displays are emerging applications that can benefit from III-nitrides based light emitters. When projecting an image, lasers are not well-suited because of the ubiquitous speckle caused by the highly coherent light, which degrades the image quality and alters the visual comfort. To keep the temporal coherence low, and get rid of the speckles, superluminescent LEDs (SLEDs) are ideal devices. They inherit the light directionality from the laser while keeping an LED-like broad spectrum. In this special issue, we learn how the linewidth of an SLED spectrum can be significantly increased compared to that of a laser.

The Auger effect is now commonly accepted to be mainly responsible for the efficiency droop of InGaN based LEDs. Another article in the feature issue theoretically addresses this and highlights the role of InGaN alloy potential fluctuations on Auger recombination processes. This theoretical study provides useful insights into the complex electronic processes that occur in InGaN alloy.

The last article in this feature issue is a comprehensive study of the recombination mechanisms that take place in deep ultraviolet (UV) emitting LEDs. These devices are very promising for disinfection and could be of paramount importance in countries where grid access is difficult, if not out of reach. So far the efficiency of deep UV LEDs is limited. This article digs into the physics of the active region and identifies parasitic radiative transitions, which should eventually be eliminated to realize a breakthrough in deep UV LED performance.

We hope that the reader will find these articles illuminating (pun intended!) and that they will expand one's imagination regarding what may be possible with advancements in LED technology in the coming years.