microLED Testing and Inspection: Challenges and Emerging Solutions

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ABSTRACT

microLED continues to be a tantalizing option for display manufacturers, due to the many advantages and consumer applications (e.g., AR and VR) that microLED offers. However, the industry continues to struggle with some fundamental problems in testing and inspection. Recent advancements in microLED testing and inspection provide a path forward.

1. Introduction

The display industry continues to invest time and capital into furthering the development of microLED technology. One of the unique aspects of microLEDs is that it comprised of single-micron sized active emissive chips. Accordingly, microLEDs offer a number of advantages over the current leading display technologies, including brighter colors, true blacks, higher resolution, reduced power consumption, and the ability to produce flexible form devices. These promising advantages enable a variety of new consumer applications, e.g., AR/VR displays, wearable devices, flexible smartphones, rollable displays, etc.

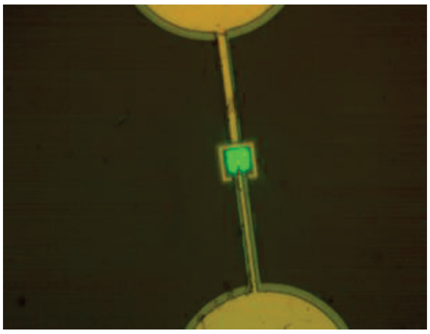

Figure 1. Green microLED

A number of obstacles still remain before microLEDs can become truly commercially viable, including complex testing and manufacturing challenges. microLED developers are currently seeking testing and inspection tools that can provide sub-micron resolution and correlated optical and structural characterization. Compounding the challenge is that wafers can contain millions of such microLEDs. And while previously, display testing and inspection could simply employ standard optical technologies for imaging and light collection and analysis, many of these methods have been rendered inadequate for the high standards imposed by microLEDs.

In this paper, we will offer a brief overview of the testing and inspection criteria that leading microLED companies have indicated to be the most critical for effectively advancing microLED technology to the point of commercialization. We will also indicate some methodologies that have recently been developed that address these specific demands.

2. microLED Testing Criteria

3 key testing criteria in microLED metrology will be outlined below.

2.1 EQE (External Quantum Efficiency)

EQE (External Quantum Efficiency), which measures the ratio of the light emitting from a microLED as a function of current, is a metric for fundamental analysis of microLED efficiency. Only by effectively collecting and processing the light from the microLED and its surrounding area is one able to accurately measure the efficiency of the microLED. While theoretically one method for performing such testing would be to employ an integrating sphere, this is both slow and also inadequate, as there are losses in sensitivity in the region <10 µ's.

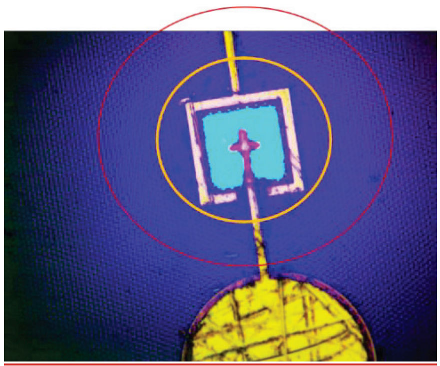

Figure 2. Image and Schematic of EQE measurements obtained with InZiv's OmniPix collecting light above and around the microLED

2.2 Angular Measurements

Assessing the efficiency of the microLED must also be accompanied by the careful analysis of the angular divergence of the light being emitted by the microLED, and the correlation of this emission with structural defects. The scope of such measurements includes challenging locations such as the emission from the sidewalls of the microLED.

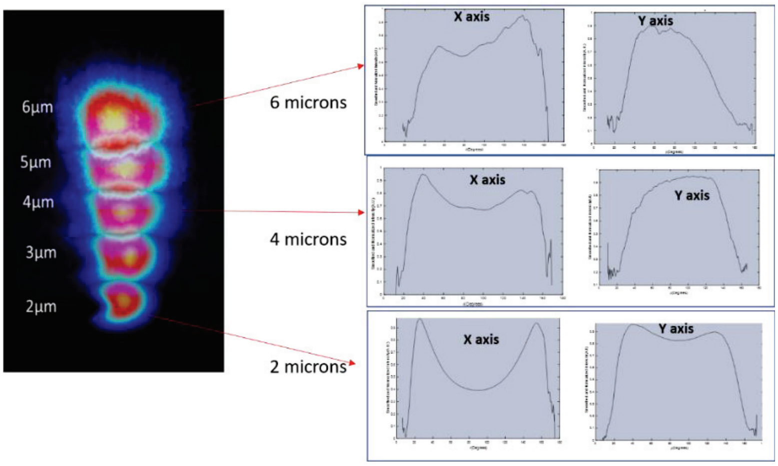

Figure 3. Imaging angular divergence above a microLED with representation in polar coordinates

2.3 Nano-Optical Resolution

Given the single-micron size of microLEDs, it is critical to be able to image with light at the highest resolutions that are well below the diffraction limit, as high as 100nm. Standard Photoluminescence (PL) and Electroluminescence (EL) only show intensity. On the other hand, nano-Electroluminescence (nano-EL) and nano-Photoluminescence (nano-PL) compare not only the intensity of the light but also the optical distribution. The ability to compare EL/PL on the same platform both in terms of intensity and distribution provides essential data in correlating the defects between EL/PL. The more this methodology is developed, the better the ability to compare and understand the correlation between EL and PL defects.

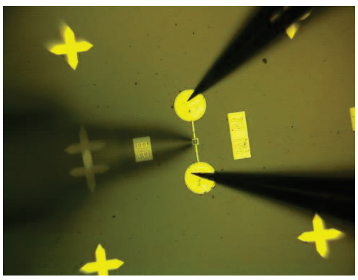

Figure 4. microLED excited with EL probes

3. Additional Testing Challenges

Some pads that surround the microLED chip can also be quite complex in both geometry and resolution. This can generate significant difficulties in contacting the microLEDS - both due to the pad dimensions themselves and their respective position vis-a-vis the microLED chip. An effective testing methodology must provide for effective and sensitive probing of electroluminescence even in these challenging environments. Moreover, in certain circumstances, a microLED die will feature very low power levels. This necessitates sensitive detectors, so that even at the lowest power levels, imaging can be effectively and rapidly accomplished. Finally, in the long term, as testing progresses to inline inspection, measurement capabilities must be performed with considerable attention to the need for speed. For inspection, speed is the most important factor (even more than accuracy).

4. Conclusion

InZiv, a leading microLED testing and inspection tool manufacturer, has recently developed a technology which addresses these core requirements in microLED characterization. The OmniPix offers a full suite of microLED testing and inspection capabilities. The system is automated and comprehensive, employing PL, EL, and nano-PL/nano-EL. The technology harnessed in this tool offers essential data such as full wafer mapping with multiple chip-level measurements such as: EQE, angular measurements, and nano-scale defect review of correlated optical, spectral, and structural data.

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