Accurate, Cost-Effective High Brightness LED Testing Starts with Device Fundamentals

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High brightness light emitting diodes (HBLEDs) combine high output and high efficiency with long lifetimes. Manufacturers are developing devices that offer higher luminous flux, longer lifetimes, greater chromaticity, and more lumens per watt. Ensuring their performance and reliability demands accurate, cost-effective testing at every phase of production.

The electrical I-V curve of a typical diode is illustrated in ***Figure 1***. Although a complete test sequence could include hundreds of points, a limited sample is generally sufficient to probe for the figures of merit. Many HBLED tests require sourcing a known current and measuring the resulting voltage or vice-versa. Instruments that combine synchronized sourcing and measurement can speed system setup and enhance throughput. Testing can be done at the die level (both wafer and package), or the module / subassembly level. At the module/subassembly level, HBLEDs are connected in series and/or parallel; therefore, higher currents are typically involved, sometimes up to 50A or more, depending on the application. Some die-level testing can be in the range of 5 to 10 amps, depending on die size.

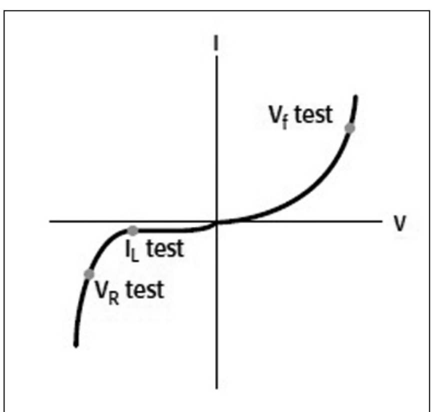

Figure 1. Typical HBLED DC I-V curve and test points (not to scale).

Forward Voltage Test

Understanding how new building-block materials like graphene, carbon nanotubes, silicon nanowires, or quantum dots will perform in the electronic devices of tomorrow demands instrumentation that can characterize resistance, resistivity, mobility, and conductivity over wide ranges. Often, this requires the measurement of very small currents and voltages. The ability to create accurate and repeatable measurements at the nanoscale level is critical to engineers seeking to develop and commercialize these next generation materials.

Optical Tests

Forward current biasing is also used for optical tests because current flow is closely related to the amount of light an HBLED emits. A photodiode or integrating sphere can be used to capture the emitted photons to measure optical power. This light is converted to a current that's measured using an ammeter or one channel of a source-measure unit (SMU).

Reverse Breakdown Voltage Test

A negative bias current applied to an HBLED allows probing for its reverse breakdown voltage (VR). The test current should be set to a level where the measured voltage value no longer increases significantly when current is increased slightly. At higher voltages, large increases in reverse bias current produce insignificant changes in reverse voltage. The VR test is performed by sourcing a low-level reverse bias current for a specified time, then measuring the voltage drop across the HBLED. Results are typically in the tens of volts.

Leakage Current Testing

Moderate voltages are normally used to measure the current that leaks across an HBLED when a reverse voltage less than breakdown is applied (IL). In production testing, it's common practice to ensure only that leakage doesn't exceed a specified threshold.

Boosting HBLED Production Test Throughput

Once, a PC controlled all aspects of HBLED production test. In other words, in each element of a test sequence, the sources and instruments had to be configured for each test, perform the desired action, and then return the data to the PC. The controlling PC evaluated the pass/fail criteria and determined where to bin the DUT. Significant time was consumed by passing commands from the PC and results back to it.

The latest generation of smart instruments, including Keithley's new High Power 2651A System SourceMeter, boost throughput substantially by minimizing communications traffic. The majority of the test sequence is embedded in the instrument in a Test Script Processor (TSP®), a test sequence engine that allows control of the test sequence, with internal pass/fail criteria, calculations, and control of digital I/O. A TSP stores a user-defined test sequence in memory and executes it on command, reducing set-up and configuration time for each step in the sequence.

LED Test System for a Single Device

The component handler transports the individual HBLED (or group of HBLEDs) to a test fixture, which is shielded from ambient light and houses a photodetector (PD) for light measurements. Two SMUs are used: SMU #1 supplies the test signal to the HBLED and measures its electrical response; SMU #2 monitors the photodiode during optical measurements.

The test sequence is programmed to begin using a digital line from the component handler that serves as a "start of test" (SOT) signal. After the instrument detects this signal, the test sequence begins. Once completed, a digital line to flag "measurement complete" is set for the component handler. In addition, the instrument's built-in intelligence performs all pass/fail operations and sends a digital command through the instrument's digital I/O port to the component handler to bin the HBLED based on the pass/fail criteria. Then, two actions can be programmed to take place simultaneously: data is transferred to the PC for statistical process control and a new DUT moves into the test fixture.

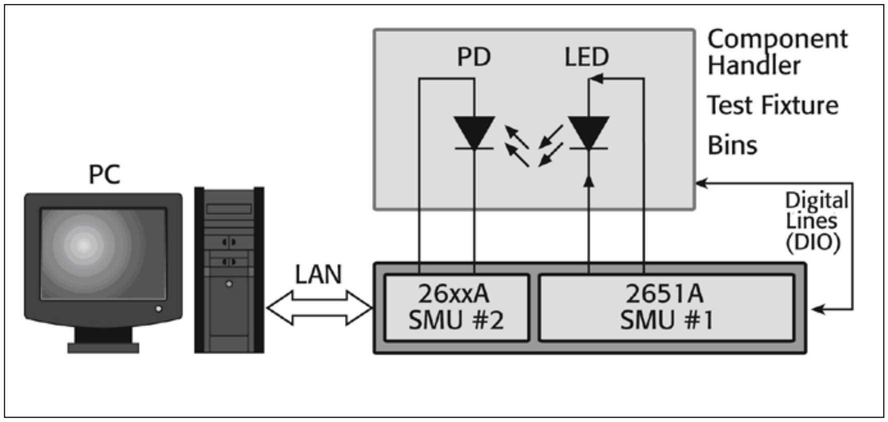

Figure 2. illustrates a system for testing one HBLED at a time. A PC and a component handler—or a probe station for on-wafer measurements—are typically included.

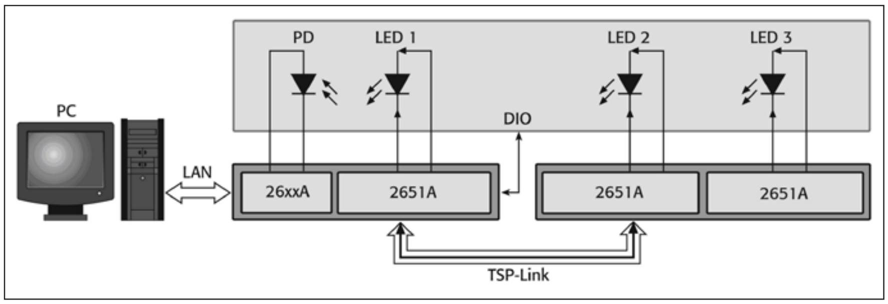

Figure 3. illustrates a three-HBLED device test system with one photodiode (PD) channel.

Testing Multiple HBLED Devices

Applications such as burn-in involve measuring multiple parts simultaneously.

Minimizing HBLED Testing Error

Junction self-heating is among the most significant error sources in HBLED production test. As the junction heats over time, the voltage drops or, more importantly, the leakage current increases, so it's crucial to minimize test times. Smart instruments can simplify configuring the device soak time (which allows any circuit capacitance to settle before the measurement begins), as well as the integration time (which defines how long the A-to-D converter acquires the input signal). New SMU instruments, such as the Keithley 2651A, have digitizing A-to-D converters, which can sample at speeds up to one microsecond per point, which is up to 50 times faster than high-performance integrating A-to-D converters. These higher measurement speeds further improve overall test times.

The use of pulsed measurements minimizes test times and junction self-heating. Modern SMUs with high pulse width resolution ensure precise control over how long power is applied to the device. Pulsed operation also allows these instruments to output current levels well beyond their DC capabilities.

For examples of HBLED test sequence script code, ***download Keithley's Application Note 2639, High Speed Testing of High Brightness LEDs***. KEITHLEY

Biographical Note:

Mark A. Cejer is a marketing director for Keithley Instruments, Inc., Cleveland, Ohio, which is part of the Tektronix test and measurement portfolio. He joined Keithley in 1991. During his tenure, he has served in a variety of positions, including marketing engineer, product/marketing manager, regional sales manager, and business manager. In his work, he has helped define and launch a number of Keithley's most popular instruments, including many of the company's SourceMeter® instruments, digital multimeters (DMMs), and datalogging products. Before joining Keithley, he served in several project management and electrical engineering positions in the electronics industry with emphasis on aerospace/defense. He holds a BSEE from the University of Akron (Akron, Ohio) and an MBA from Case Western Reserve University (Cleveland, Ohio.) His technical interests include compound semiconductors for power, LED, and energy efficiency applications, as well as optical devices, sensors, and discrete semiconductors.

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