CALIFORNIA STATE SCIENCE FAIR
2010 PROJECT SUMMARY

Name(s)
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Project Number
S0905

Project Title
Investigation of the Efficiency Droop Mechanisms in Wide Bandgap Light Emitting Diodes (LEDs)

Abstract

Objectives/Goals
Light emitting diodes (LEDs) are currently increasing in terms of application to lighting and electronic devices. However, it has been noted that LED efficiency is inconsistent; efficiency often decreases with increasing current. This experiment observes the effect of increasing current on various LEDs in order to determine the cause of this so-called LED efficiency droop phenomenon.

Methods/Materials
Red and Yellow InGaAlP based LED (Non-polar); Blue and Green InGaN based LEDs (Polar)
Electroluminescence meter
Pulsed current supply with computer control
Spectrometer

Results
Observing the EQE (efficiency) charts (which show the ratio if light power output to light input vs. current), both red and yellow LEDs are shown to have an power input/ light power output ratio beginning at 30% and increasing to about 35% before beginning to drop. The current at which efficiency begins to drop is approximately 30-50 mA. The blue and green LEDs have efficiencies that drop immediately. Efficiency drops from a high efficiency (about 61% green; 57% blue) to a low (18% green; 23% blue)for polar LEDs. The efficiency drop in these LEDs occur at around 3 mA.
The nonpolar LEDs exhibit redshifts, or change in wavelengths, as the input currents increase, made clear by the EL Spectra. The blue and green LEDs exhibit no significant change in wavelength as the current increases.

Conclusions/Discussion
Red and Yellow LEDs (non-polar) show an efficiency droop beginning at a much higher current input that that of the blue and green (polar) LEDs. The source of the efficiency droop in the non-polar LEDs is due to the joule heating effect, shown by the redshift. The change in wavelength of light shows that heat damage (due to resistance of the diode and the input current) has degraded the LED; not only is the wavelength of light changed, but the efficiency is affected as well. However, the blue and green LEDs do not demonstrate this joule heating effect. Thus, there is no way to conclude the source of the efficiency droop in these diodes.
My hypothesis was only partially correct: internal resistance and heat degradation only appears to affect LEDs made of non-polar semiconducting materials. It seems that the source of the efficiency droop is more complicated in polar LEDs due to the different polarity of the semiconducting materials.

Summary Statement
Exploring the efficiency droop of polar and non-polar LEDs in relation to increased input currents.

Help Received
Used lab equipment at Blue Photonics Inc. under the supervision of Dr. Milton Yeh.