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Internal Resistance of an LED as a function of Temperature

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Abstract

The relationship between internal resistance and the operating temperature was investigated for a 5 mm green LED. A potential difference of 3.00 V was put across the LED and the current through it was recorded for different operating temperatures. It was found that there is an exponential relationship between the internal resistance and the inverse of temperature.

Introduction

A diode has a p-region that has extra positively charged carriers and an n-region that has extra negatively charged carriers with a junction between the two regions. When a voltage is put across a diode, with the n-region connected to the negative electrode and the p-region connected to the positive electrode, electrons move from the n-region to the p-region. When electrons move across the junction of a light-emitting diode, the electrons drop to a lower energy level and release energy in the form of photons. [1]

The operating efficiency of LEDs, like many electrical devices, depends on the temperature. The effect of temperature on the resistance of a semiconductor diode differs from the more commonly studied effect of temperature on the resistance of a metal. In this research, the relationship between the operating temperature of a light-emitting diode and its internal resistance will be investigated.

The theoretical relationship between the internal resistance and the temperature of an LED is

$$I_{total} = I_o \, exp^{(-eV/\eta kT)} \quad [2] \qquad \text{(Equation 1)}$$

where I_o is the reverse saturation current of the diode, e is the charge on an electron, V is voltage, η is the ideality factor which varies from diode to diode, and k is Boltzmann's constant.

Rearranging gives $$R = (V/I_o)e^{(eV/\eta kT)}$$

and $$R = Ae^{(B(1/T))} \qquad \text{(Equation 2)}$$

where T is the temperature, R is the internal resistance, A is the constant V/I_o, and B is the constant eV/ηk. From equation 2, it can be seen that an exponential relationship is expected between the internal resistance of the LED and inverse of the temperature.

Methods

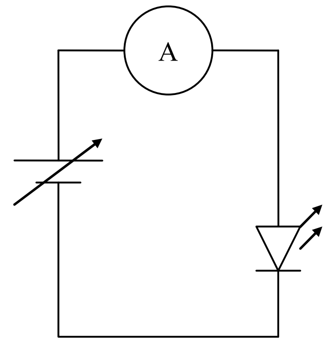

Figure 1 Circuit Diagram.

A 5 mm green LED[3] with an emission wavelength of 543 nm was connected in series to a DC voltage source and an ammeter. A beaker with ethyl alcohol and dry-ice was placed on a hot plate. A thermocouple was attached to the LED using tape. The LED was then placed inside a clear plastic bag and put inside the beaker with the opening of the plastic bag above the solution. The LED was kept in the beaker for 15 minutes for thermal equilibrium to be achieved at the coldest temperature.

The temperature was recorded and the LED was turned on by putting 3.00 V across the LED. The current was recorded. The LED was turned off for 10 seconds between each trial to allow the LED to return to thermal equilibrium. Three current readings were recorded for each temperature. After the first set of data was taken, the hot plate was turned on and the temperature of the bath gradually increased. Data was taken at temperatures ranging from 235±1K to 351±1K.

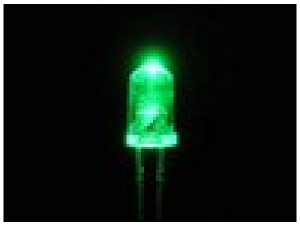

Figure 2 5 mm green LED[3]

Results and Discussion

From figure 3, the relationship between internal resistance of an LED and the operating temperature is given by the equation:

$$R = (5.9 \pm 0.7\ \Omega)\ e^{(1500 \pm 30K(1/T))} \quad \text{(Equation 3)}$$

There is an exponential relationship between the internal resistance and the inverse of temperature for temperatures from 235±1K to 351±1K.

For this curve fit, however, the lowest points do not fit the curve. The resistance does not appear to approach zero at very high temperatures.

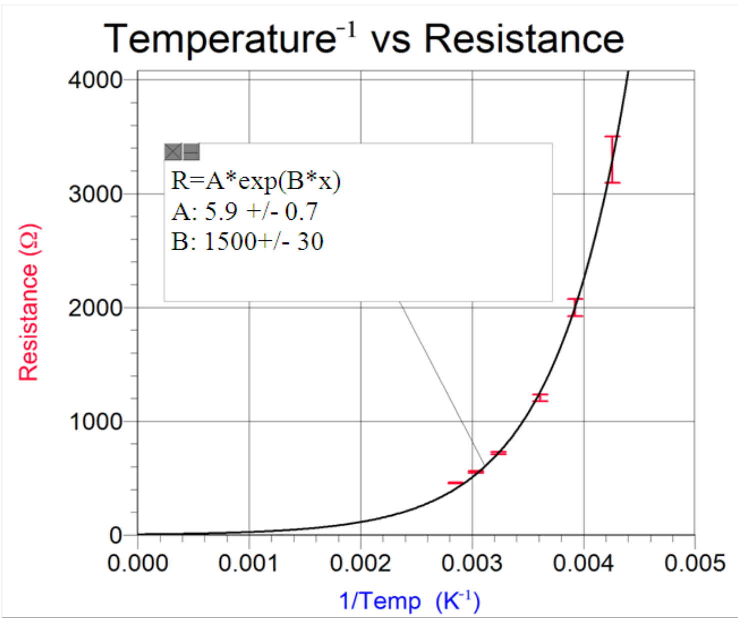

Figure 3 Internal resistance of an LED versus inverse temperature with a theoretical curve fit.

Another equation, including a constant, can be fitted to the data

$$R = (3.0\pm0.9\Omega)\, e^{(1600\pm60K(1/T))} + 130\pm50\ \Omega \qquad \text{(Equation 4)}$$

as shown in figure 4. This curve fits the data better than equation 3 but it does not agree with the accepted theory. It is not understood why a constant C added to the theoretical equation fits the data better.

By using equation 4, the temperature can be determined by putting a known voltage across the LED and measuring the internal resistance. An LED can act as a thermometer. It should be noted that since the constants eV and η are different for every LED, each LED thermometer would have to be calibrated individually.

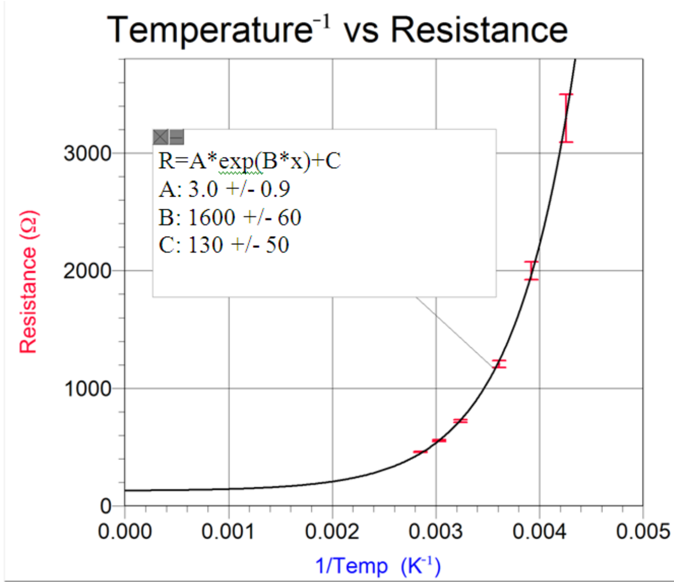

Figure 4 Internal resistance of an LED versus inverse temperature with an $Ae^{B*x}+C$ curve fit.

A weakness in the method was that the thermocouple was taped on the outside of the plastic housing of the LED. The actual diode material could have been at a higher temperature than the reading on the thermocouple, due to heating as the current flowed through the diode. To avoid this, an LED with a thermocouple imbedded inside the plastic housing can be constructed.

Further research is suggested to confirm the relationship between the operating temperature of an LED and its internal resistance for a variety of LED colors and types. A technique should be devised with the temperature sensor in contact with the diode material and tests done over a wider temperature range.

Conclusion

The relationship between the internal resistance of an LED and operating temperature was found for a 5 mm green LED with 3.00V put across it. The relationship between the internal resistance and temperature^{-1} is exponential for temperatures from 235±1K to 351±1K.

References

[1]How Light Emitting Diodes Work. Retrieved November 8, 2009, from Howstuffworks: http://electronics.howstuffworks.com/led2.htm

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[3] Alan Parekh's Electronic Projects. Retrieved November 20, 2009, from http://alan-parekh.vstore.ca/print_catalog.php