INVESTIGATING LED THERMOCHROMATISM

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BACKGROUND

A Light Emitting Diode (LED) is a semiconductor device that emits light when an electric current passes through it. As electricity flows, electrons move and recombine with holes at the junction between two semiconductors, releasing energy in the form of photons (light). The color of the light is determined by the semiconductor's bandgap, which is dependent on temperature. When an LED is cooled to extremely low temperatures, such as with liquid nitrogen, the bandgap energy increases. This causes the LED to emit higher-energy photons with shorter wavelengths, resulting in a slightly brighter light and a small shift toward the blue end of the spectrum, known as a “blue shift.”

PURPOSE

The purpose of this experiment is to explore how changes in temperature affect the behavior of electronics, particularly LEDs. Liquid nitrogen provides us with the opportunity to explore the science behind how light and energy work together under extreme conditions. Additionally, we were also drawn to the hands-on aspect of circuit-building and experimentation. This research has real-world relevance, as electronic devices such as LEDs must function reliably in harsh, freezing environments like those encountered in space aboard spacecraft, satellites, and telescopes as well as cryogenics in superconductivity technology.

METHODS

The materials that were used in our experiment were liquid nitrogen, LEDs: red, orange, yellow, green, blue, purple, wires, Arduino: 4.92 watts, resistors, multimeter, and safety equipment: Styrofoam container, cryogenic gloves, forceps. To investigate LED at extreme low temperatures we started by assembling a circuit to power the LED. We then dunked LED lights into liquid nitrogen in a variety of tests and observed the lights before and after. This will answer our question of, how do LED lights react when exposed to extreme low temperatures?

Our hypothesis is, LEDs will glow brighter in liquid nitrogen due to reduced resistance in the circuit at lower temperatures, different color LEDs will react differently due to differences in energy band gaps, and LEDs may stop working temporarily due to thermal stresses or brittleness but will recover when returned to warmer temperatures.

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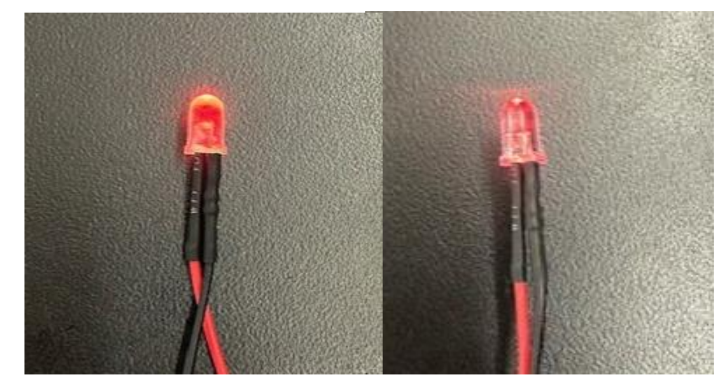
RESULTS

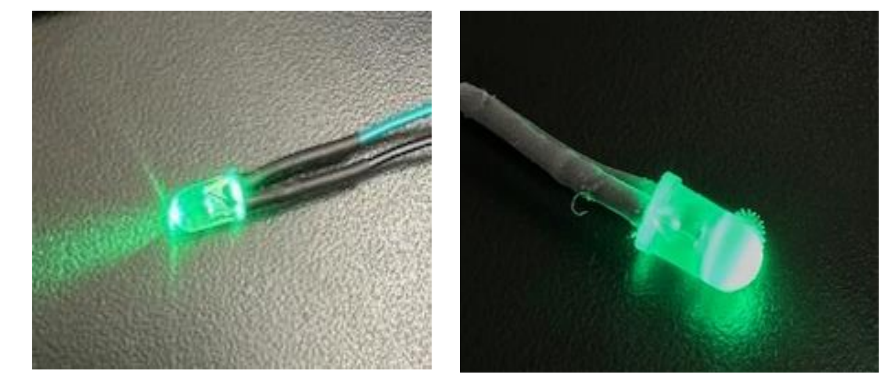
The color and brightness of the LEDS remain the same despite being placed in extreme temperatures, ~77 K using liquid nitrogen. The green, yellow, orange, and blue LEDs developed a "frosted" appearance from moisture freezing, but their color, brightness, and function remained unchanged. The red and purple LEDs showed the most visible physical change–both appeared more frosted, emitted a small amount of smoke, and was slightly dimmer.



Before After

Red LED:

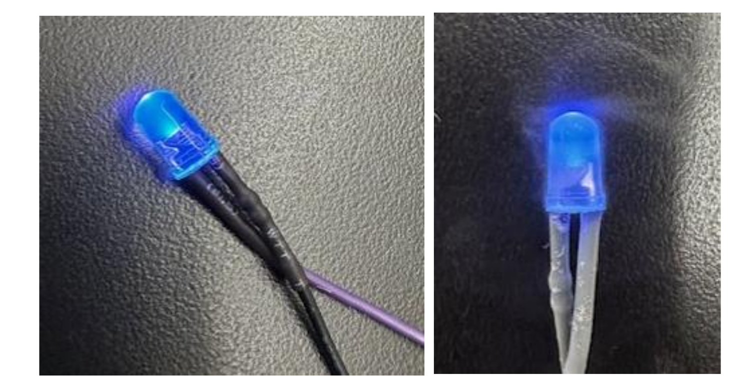
The red LED remained lit while submerged in liquid nitrogen for 30 seconds. Afterward, it appeared frosted with visible condensation, but continued to function normally when connected to the circuit.



Before After

Green LED:

After being submerged in liquid nitrogen for 1 minute while powered, the green LED showed frost on both terminals, but remained unchanged in color and brightness, continuing to glow steadily.



Before After

Purple LED:

The purple LED developed frost on both terminals after being dunked in liquid nitrogen for 2 minutes while powered. It continued to glow purple but appeared slightly dimmer than before.

ANALYSIS

Our results suggest that the LEDs consistently functioned under cryogenic conditions–however, several experimental factors may have influenced the outcomes. The depth and amount of liquid nitrogen could have affected how quickly each LED cooled, potentially impacting resistance and brightness. Since temperature can vary slightly at different depths, some LEDs may have experienced more extreme cooling, explaining subtle differences such as the dimming of the purple LED. By limiting variables, such as testing the same or all LED colors, we could better isolate how temperature alone affects light emission and resistance. Ultimately, while LEDs remained functional, small variations in brightness may be associated to differences in temperature exposure and corresponding changes in electrical resistance.

REFERENCES

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