Why Do LEDS Lose Their Brightness?

LEDs do not burn out suddenly like the incandescent light bulb but fade gradually through a process known as lumen degradation. An LED can lose 30% of its initial brightness before it is noticeable to the eye. To comprehend why LEDs experience this fading, it is essential to first understand how they operate.

What Is an LED?

LEDs, or light-emitting diodes, use semiconductor chips to produce light. A semiconductor is a material with specific properties capable of conducting electricity. When an electrical current passes through the LED, a reaction inside the chip produces light. The number of chips an LED contains depends on the LED's intended use. For example, a household light bulb will use multiple chips simultaneously while indicator LEDs, such as those in an MTI product, only use one chip per LED. LEDs can produce different types of light including infrared (IR), ultraviolet (UV), and visible light.

How LEDs Are Made

Semiconductors are usually compounds consisting of several elements such as indium and gallium. Different semiconductors produce different kinds of light. Indium gallium nitride (InGaN) is used for UV, blue, and green LEDs; aluminum indium gallium phosphide (AlInGaP) for yellow and red LEDs; and gallium arsenide (GaAs) for IR LEDs [1]. White LEDs are made using a special phosphor coating on a blue LED or a combination of red, blue, and green chips to produce white light.

LED chips can be as thin as a piece of paper and have many semiconductor layers. The base layer of the chip, referred to as a wafer, is made using a process called wafer fabrication where the material is sliced into extremely thin discs [2]. The semiconductor layers are applied to the surface of the wafer at the atomic level using chemical processes.

The atoms of the semiconductors are arranged in structures called crystal lattices. Sometimes these structures form defects called dislocations during the manufacturing process [2]. Imagine a simple tiled floor, neat and orderly, with a clear pattern. Now imagine one of the tiles was placed too far over, impacting the placement of the tiles around it and disrupting the pattern. The misplaced tile is a dislocation because it deviates from the pattern. Dislocations are easy to spot in something as big as a floor pattern but require a very powerful microscope to see in the semiconductor layers.

How LEDs Produce Light

The LED chip requires two types of semiconductor layers: the n-type and the p-type. These are developed by manipulating the properties of the semiconductor. The n-type layers have extra electrons (negatively charged particles), and the p-type layers have extra holes (positively charged spaces). The holes are not defects; they are similar to parking spaces. Think of the chip as a parking garage where the electrons are the cars. The n-type layers are the lower levels of the parking garage, already filled with cars, and more cars are entering the garage. The upper levels of the garage are the p-type layers where many empty parking spaces are waiting for electrons. When an electrical current passes through the LED, the extra electrons are carried from the n-type layers to the p-type layers to fill the holes in a process called recombination, and energy is released in the form of light [3].

Why LEDs Fade

Electrons require a certain amount of energy to move from the n-type to the p-type layers. Like parking spaces, the holes have fixed locations. When a hole is situated near a dislocation, it adds to the energy requirements. As a result, no light is emitted when an electron fills a hole near a dislocation [3]. Dislocations form near the base layer during the chip manufacturing process and gradually spread through the remaining layers in the same way that a crack in the pavement grows bigger as time passes. As the area affected by dislocations increases, the amount of light produced decreases. Although the LED still receives sufficient voltage and current to operate, its brightness decreases until it appears non-operational.

There are several factors that can accelerate the spread of dislocations. Like most electrical components, excess heat can have negative effects on LED chips. The chips experience thermal expansion and shrinkage as the temperature of the LED changes during operation. This thermal stress contributes to the increase in dislocations. Moisture can also affect the lifespan of LEDs, especially in hot or humid conditions. The encapsulate of the LED is the casing that holds the chip, usually made of epoxy or similar plastics [4]. When looking at an LED, this is the part that gives it a bulb-like appearance. The material can absorb moisture in humid environments or chemicals in corrosive environments and transfer this to the chip [4].

Conclusion

LEDs contain chips that produce light when current passes through them. During the manufacturing process, these chips develop microcracks called dislocations that expand throughout the LED's lifetime. The presence of the dislocations changes the energy requirements of the recombination process that generates light. As a result, the areas near the dislocation do not produce any light. As the dislocations spread throughout the structure of the chip, less light is emitted, and the LED decreases in brightness. Even though the LED is no longer visibly lit, testing with a voltmeter will still show the LED is functional.

References

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