

Silicon Carbide Light Emitting Diode Fabrication and Characterization

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Abstract:

Light emitting diodes or LEDs are the next level of technology when it comes to a light bulb. LED technology is about finding a semiconducting material that emits different color light. This project focused on what a LED is and how it works. We also discuss silicon carbide (SiC) LED fabrication and characterization.

Talking about LED briefly, it is a semiconductor diode that emits incoherent monochromatic light when electrically biased in the forward direction. This report will explain in detail how this device emits light and how it emits multi-color light by using different semiconductor material. To understand this, there will be a brief explanation of what a semiconductor and a diode are. We will be explaining silicon carbide which is the semiconductor material that we used to fabricate the LED while working in the lab.

Also, we will explain in this paper the fabrication technique that we followed in processing this device. Pictures and photos of this device will be included. In the results and conclusion, we will give opinions on LED performance, and compare and contrast the LED bulb to the incandescent bulb of today.

Introduction:

What is a light emitting diode? LEDs are special types of semiconductor diodes that emit incoherent monochromatic light when electrically biased in the forward direction. Like a normal diode, the LED consists of a chip of semiconductor material impregnated or doped with impurities to create a structure called a pn junction. The junction consists of a p-type and n-type semiconductor regions. The p-type semiconductor has an excess of conducting holes which are created by adding trace amounts of other elements to the original pure semiconductor crystal. The n-type semiconductor has an excess of conduction electrons which can be made n-type by adding trace amounts of another element to the semiconductor crystal.

Before any light is emitted, another region is formed in the middle of the diode called the depletion region. The depletion region is formed because the negative charges attract with the positive charges along the junction. This creates a neutral charge in the junction where the electrons and holes can't move.

To fix this problem, an electric field has to be applied and when sufficient voltage is applied to the chip across the leads of the LED, electrons can move easily in only one direction across the junction between the p and n regions. In the p region, there are more positive charges than negative. In the n region, there are more negative charges than positive. As current passes thru the junction, the electrons combine with the holes and this recombination gives off energy in the form of light which can be called photons. When all free holes and electrons combine, they produce enough light to be emitted through the bulb. We can see this process in Figure 1.

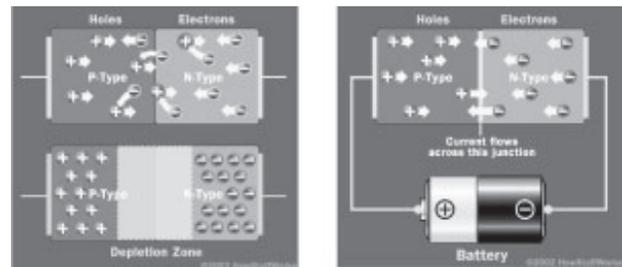


Figure 1: PN junction diagram of how the LED works.

To produce different color light, you use different kinds of semiconductors. Silicon carbide (SiC), indium gallium nitride (InGaN), and zinc selenide (ZnSe) produce blue LED's. Gallium phosphide (GaP), and gallium nitride (GaN) produce green LED's. Gallium arsenide/phosphide (GaAsP) produce red, orange and yellow LED's. Aluminum gallium arsenide (AlGaAs) produces red and infrared. When blue, red, and green are combine, they can produce white LED's, and the white light is the most expensive diode to make.

Procedure:

For fabricating the device, we used photolithography. The following are the procedures to follow when fabricating the SiC substrate:

Cleaning Process (To be done at wet bench): Apply soap solution with brush in one direction. Rinse in DI water and blow dry with nitrogen gas. Ultrasound with trichloroethylene, acetone, and methanol for three minutes without exposing to the air. Rinse in DI water and blow dry with nitrogen gas. Place sample in pre-bake oven for 5 minutes to dry off any residual moisture on the surface.

Lithography Process (To be done under yellow light): Turn on spinner and place sample. Turn on vacuum pump, then apply a few drops of photoresist (Shipley 1818 "4:1") to sample surface. Cover spinner and spin sample on a 1.4 μm thick layer in 30 sec. at 6000 rpm. Remove sample from spinner and place in the pre-bake oven for 30 min. at 105°C. Turn on mask-aligner lamp and main power. Remove sample from pre-bake, let cool, then expose to UV light for 18 sec. Use fume hood to develop. Dip sample in toluene for 60 sec. (this hardens the surface), rinse & dry with nitrogen. Dip sample in developer (gently agitating) for 60 sec, rinse & dry with nitrogen gas. Repeat process for each layer.

Electron Beam Evaporator: Turn on power. Deposit 100 Å Aluminum to create p-type region on substrate, then anneal at 650°C for 60 sec. Ohmic contact of (50Å/400Å/1500Å) chrome, nickel, gold, respectively, for probing n-type region, then anneal at 650°C for sec. Transparent layer of (50Å/100Å) chrome, gold for p-type region. Metallization contact of (50Å/400Å/1500Å) chrome, nickel, gold for probing p-type. See Figure 2.

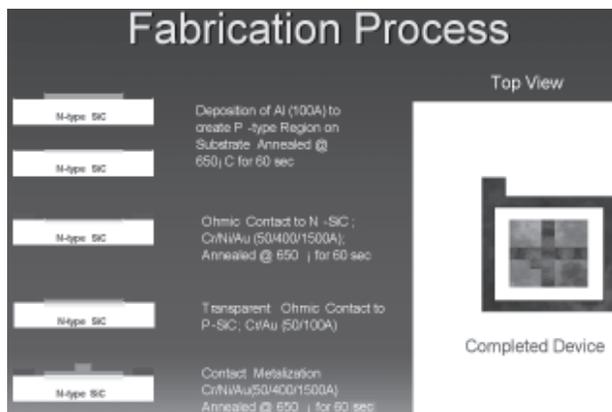


Figure 2: Procedure for using the e-beam evaporator.

Results and Conclusion:

After fabricating and probing the device, results were obtained showing that the diode had a characteristic curve (current vs. voltage) with a turn-on voltage that was greater than 0.7 V with a doping concentration of 10^{18} cm^{-3} . Also, the light that was produced had very low light intensity and low light efficiency. Refer to Figure 3.

In conclusion, we have fabricated a preliminary light emitting diode (LED) with a fair characteristic curve (current vs. voltage) that had low levels of light intensity. In future work, we intend to work more on changing the device structure and then measuring the intensity and spectrum of the light. Also, we can characterize the parameters by the doping concentration, the junction depth, and the mobility of the p- and n-type regions. Last, we can then package the device in the bulb.

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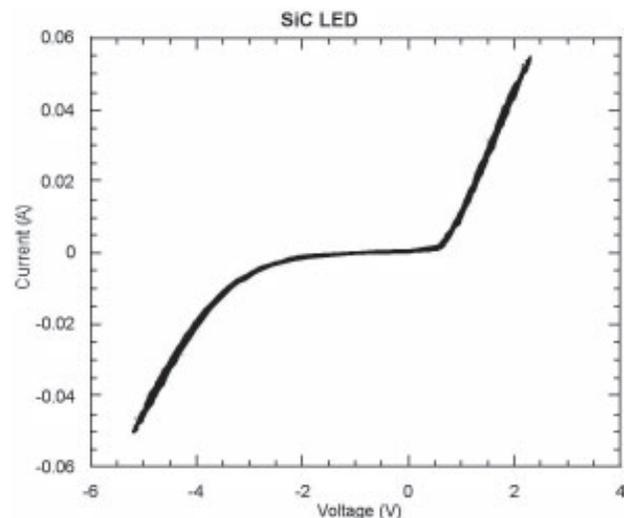


Figure 3: Characteristic curve showing current vs. voltage.