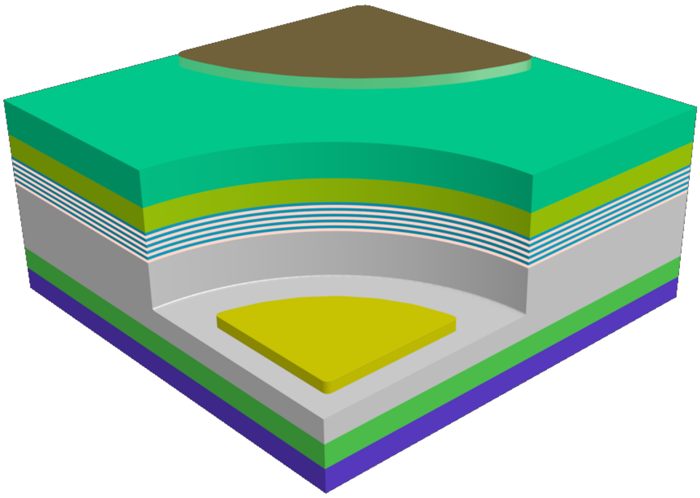
Light emitting diode on GaN

Classical Drift Diffusion



Xiences GmbH

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Executive Summary

This is a document describing an example project for the **XienceSim** software.

Note The XienceSim environment is a Finite element software package designed to solve complex physical problems. It is capable to handle 1,2 and 3 dimensional structures, with various analysis types: stationary, periodic, time dependent, eigenvalue. We hope that you are going to find our tutorial useful, comments are well appreciated: info@xiences.com.

Editor: Zoltan Jehn

1 Introduction

In order to achieve light emission from a classical light emitting diode on lower wavelengths one should modify the band-structure. Meaning the bandgap should be larger for such devices, than what is simply achievable from zinc-blende type semiconductor materials. For this purpose we should investigate a LED structure grown on wurtzite material.

2 Structure

We simulation we used the following LED structure in figure 1. The doping for donor concentration is $N_d^+ = 2E24\frac{1}{m^3}$, while the acceptor concentration is $N_a^- = 7E25\frac{1}{m^3}$. The growth direction was in the $c \uparrow$ axis of the crytal structure, which means, the pyro, and piezo effects are also should be considered.

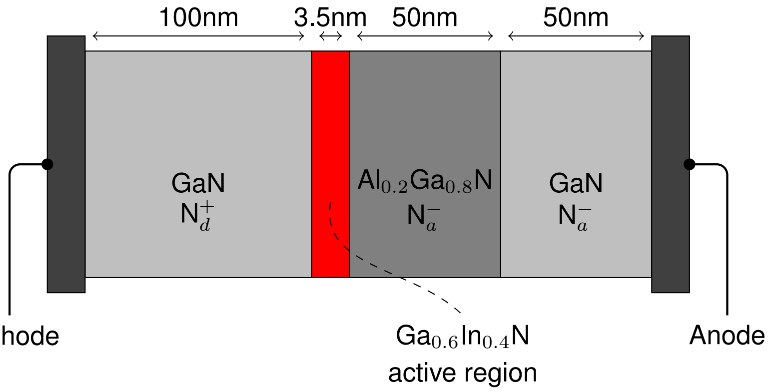

Figure 1: Structure of the LED

3 Bandstructure at zero bias

The bandstructure of the device is plotted in figure 2. It shows that the polarization charges band the profile to the opposite direction as the pn junction would do. For clarification built in potential with, and without polarization charges is depicted in figure 3, while the polarization charges are depicted in figure 4.

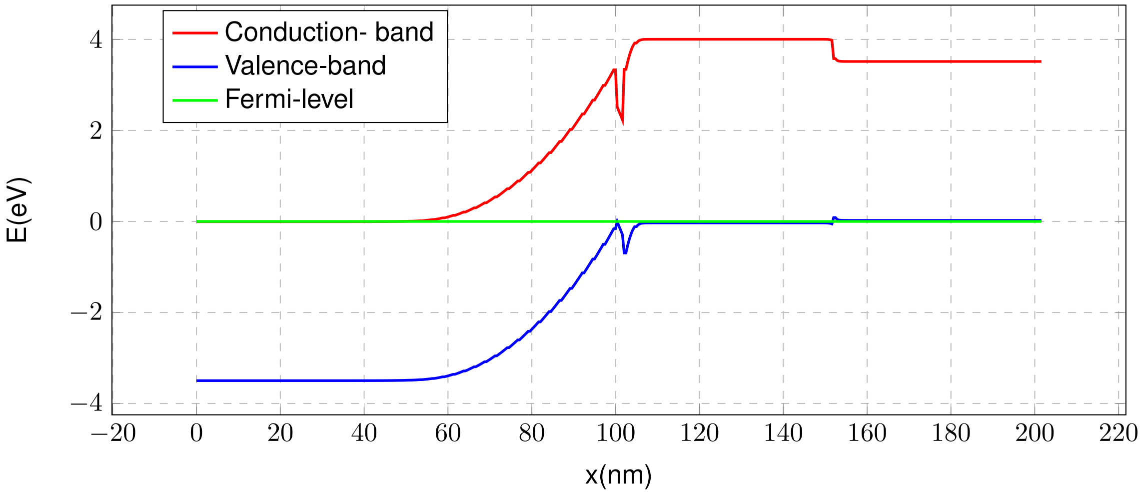

Figure 2: Bandstructure at zero bias.

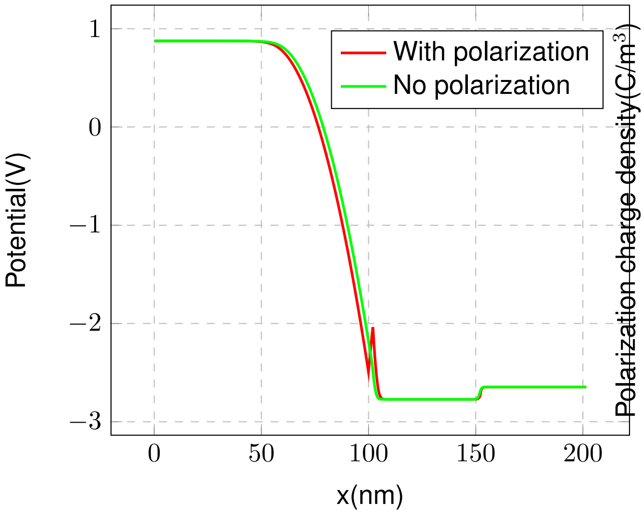

Figure 3: Built-in potential

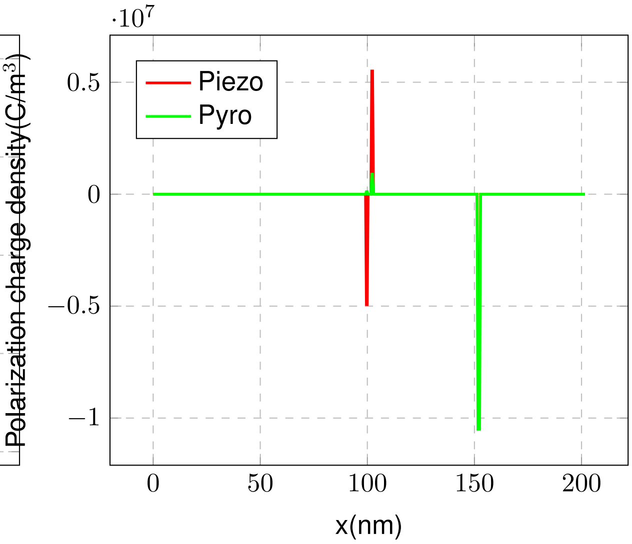

Figure 4: Piezo and Pyro charges in the structure

4 Active region

The active of th device is built from InGaN alloy, due its lower bandgap, which results higher carrier concentration in that region. It is a quantum-well region, which creates a confinement for both electron and hole state. The ground state eigenfunctions for this confinement is plotted in figure 5 for electrons, and the heavy-holes.

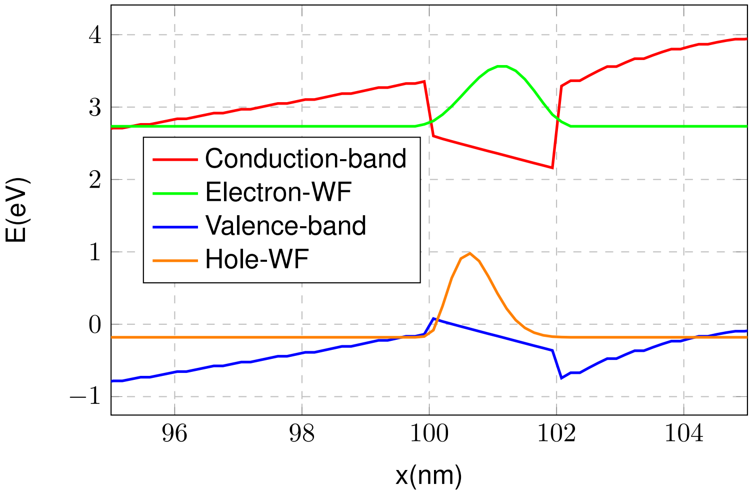

Figure 5: Active region of the device with plotted electron and hole eigenfunctions in the quantum well.

5 Voltage Characteristics

If we apply bias on the device, we inject carriers to the Quantum well, and those could recombine which process results a photon. The radiative recombination process can be included in the solution of the carrier transport equations, alongside with other non-radiative recombination processes, such as SRH and Auger recombination in our simulation.

We can calculate the internal quantum efficiency of the device defined as:

$$IQE = \frac{\sum Radiativerecombinations}{\sum Allrecombinations}, \tag{1}$$

which means we should integrate the full recombination and radiative recombinations in the device. And the ratio is the efficiency factor. The internal quantum efficiency is plotted in figure 6 around its maximum.

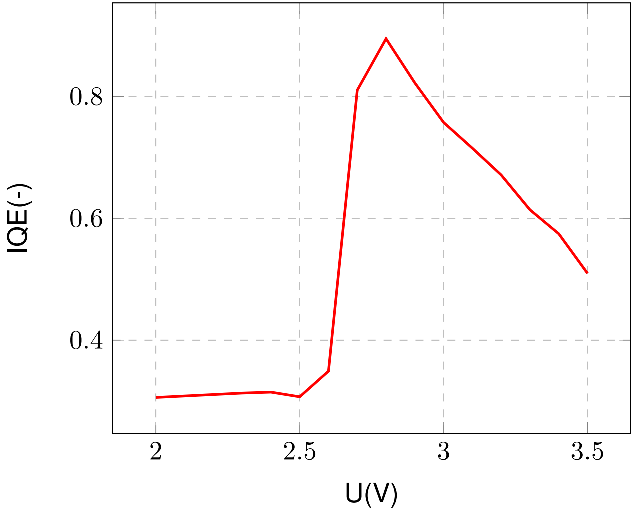

Figure 6: Internal quantum efficiency maximum

6 Gain spectrum

For various bias voltages we can calculate absorption, emission, and gain spectrum of the active region in the device. For various bias voltages it is plotted in figure 7. here we neglected the imperfections in the quantum well, which would round down the edge of the emission/absorption curves.

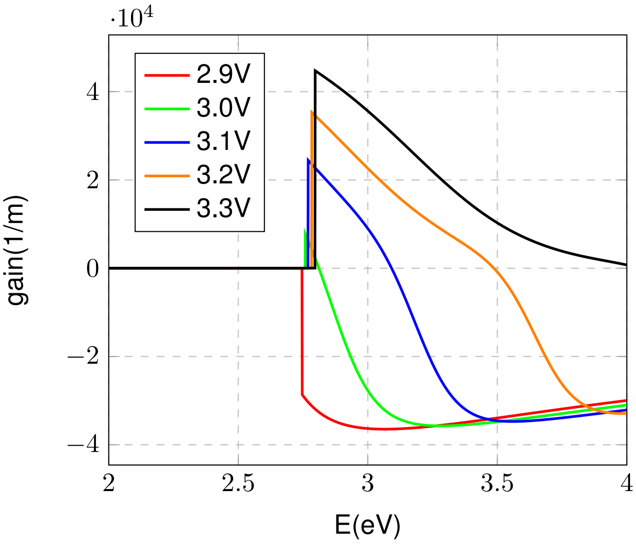

Figure 7: Gain spectrum of the device for various bias voltages.

7 Online materials

The full tutorial can be found at the website **http://xiences.com**, with example project files.

References