Design, Simulation and Characterization of Organic and Inorganic LED/(DSOI-LED)

Call for Proposals 2021 - AASTMT

Electronics and Communications Engineering, El Alamein

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Keywords: Light Emitting Diode; GaN-based LED, Multiple Quantum Well, Organic LED, SiLENSe, LED Characterization.

Funding and Duration: 12 Months for the CRP

Total cost: 288,000 LE

Research Theme: Electronics and Communications Engineering

1. Proposal Summary

This project has two goals. First, using the SiLENSe software to investigate the possibility of using InGaN/GaN/InGaN multi quantum well (MQW) structures to get output different colors. By changing the parameters and composition of indium in the wells, different colors: blue, green, yellow and red LED could be achieved. The design of the LED is accomplished by using the Semi Bulk (SB) approach which is based on GaN/InGaN superlattice structure to enhance the relaxation in the quantum well layers. Further, some proposed ideas to mitigate the efficiency droop encountered in GaN-based LEDs will be conducted.

Second, we intend to prepare an organic light emitting diode (OLED) by spin coater and spray pyrolysis coater. In general, organic devices have the potential for cost advantages over inorganic devices. In addition, inherent properties of organic materials, such as their flexibility make them well suited for particular applications such as fabrication on a flexible substrate.

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هناك هدفان لهذا المشروع المقدم. أولاً: يتم استخدام حزمة برنامجSiLENSe للتحقق من إمكانية استخدام نبائط الصمام الثنائي الباعث للضوءInGaN/GaN/InGaN LED متعددة الآبار الكمومية (MQW) لإخراج ألوان مختلفة (مثل الأزرق والأخضر والأصفر والأحمر). حيث يمكن تحقيق ألوان مختلفة من خلال تغيير معايير وتكوين الإنديوم في هذه الآبار. ويتم إنجاز تصميمLED باستخدام نهج Semi Bulk (SB) الذي يعتمد على بنية الشبكة الفائقة GaN/InGaN لتعزيز الاسترخاء في طبقات البئر الكمومية. وعلاوة على ذلك، سيتم إجراء بعض الاقتراحات لتقليل تدني الكفاءة في مصابيحLED القائمة على GaN.

ثانيًا ، نعتزم تحضير نبيطة الصمام الثنائي العضوي الباعث للضوءOLED)) عن طريق المغلف بالدوران وغطاء الانحلال الحراري بالرش. وبشكل عام، تتمتع النبائط العضوية بإمكانية الحصول على مزايا من حيث التكلفة مقارنة بالنبائط غير العضوية. وبالإضافة إلى ذلك، فإن الخصائص الكامنة في المواد العضوية، مثل مرونتها، تجعلها مناسبة تمامًا لتطبيقات معينة مثل التصنيع على ركيزة مرنة.

2. Introduction

In 1803, Humphry Dey was first able to show light generation from an arc lamp using charcoal rods. This encouraged designers to develop upon this design; finally ending in Thomas Edison's research in the conventional incandescent bulb. Unfortunately, due to the power demands of such lighting structures, research moved to florescent bulb technology in the early 20th century. However, this was an ineffective lighting structure. With the world increasingly modernizing, the demand for power and lighting grew. In addition to being inefficient, such systems have lifetimes that are intolerable as we move to the future [1].

By merging semiconductor physics and the idea of radiative recombination, light generation was accomplished with solid state devices. While working in General Electric, Nick Holonyak, Jr., invented the world's first visible LED in the form of red diodes. LEDs remain the quickest emerging lighting technologies. Being able to directly convert electric power to light with no intermediate steps results in large improvements in the lumens per Watt produced. Another benefit of LEDs is their long lifetimes as these structures are solid state devices [1]. However, LEDs have also their drawbacks, most of which revolve around their color accuracy. Since they are a relatively new technology, there exists a large opportunity in enhancing efficiency and color.

A Light Emitting Diode or LED is a semiconductor light source. Light is released from the structure when electric current drifts through the device. This is called electroluminescence (EL). Photons are released by the radiative recombination of electrons and holes, as shown in figure 1. Unlike wide-band sources, the wavelength of photon released is equal to the energy drop of electron to hole [2]. Thus, LEDs are not white light sources but can be sources of single wavelength light. This makes them highly efficient for colored light applications such as traffic lights.

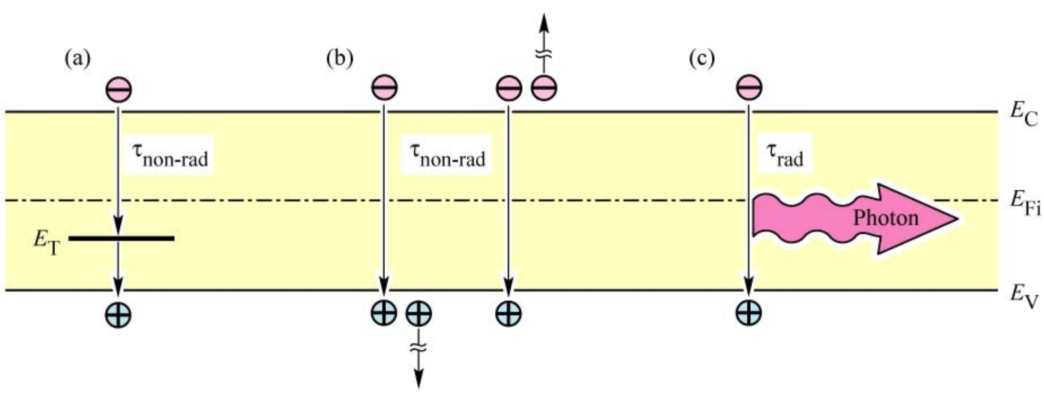

Fig. 1 Band diagram illustrating non-radiative recombination: (a) via a deep level, (b) via an Auger process and (c) radiative recombination.

The energy released in a photon, and consequently the wavelength of photon released, can be engineered using quantum wells. A quantum well is a thin layered semiconductor structure in which one can control quantum effects. The method by which a quantum well can be constructed is by sandwiching a semiconductor material of smaller band gap between semiconductor materials of larger band gaps [3]. We can understand the physics of these quantum wells by looking at Schrodinger's Equation (Equation 1) for a "Particle in a Box". The equation for the n^{th} allowed energy level is as follows:

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$$\frac{\hbar^2}{2m}\frac{d^2\phi_n}{dz^2}+V(z)\phi_n=E_n\phi_n \tag{1}$$

The wave equation sets fixed energy states with which electrons can exist inside the quantum well. Thus, the final recombination energy is a summation of the Band Gap and the Energy States in both the conduction and valence band of the quantum well. This can be visualized in Figure 2. By choosing the band gap of the bulk and quantum well material, the excited photon wavelength is engineered [3].

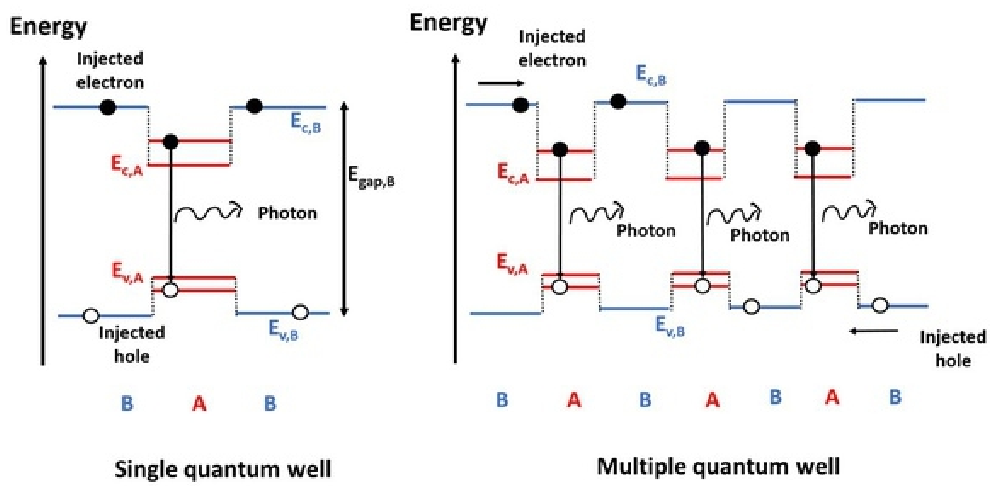

Fig. 2 radiative recombination of electron-hole pairs to release a photon of light in single and multiple quantum wells.

This project uses the SiLENSe software to simulate different types of LED structures. The modeled LEDs are based on GaN technology. In the LED design, the Semi bulk (SB) approach, which consists of an InGaN/GaN superlattice structure, is utilized. The simulation will be carried out for different colors like blue, green, yellow and red. The main physical and technological parameters will be designed in order to meet the desired output. The main output parameters that will be studied extensively are the internal quantum efficiency (IQE) and spectrum response for different biasing conditions to trace any blue or red shift occurring due to bias variation.

3. Project Objectives

a) In this work, we are planning on designing GaN-based multiple quantum well (MQW) LED different structures. The design will be performed for different colors; blue, green, yellow and red. In designing such structures, the bulk is selected in such a way to reduce the stress inside the well layers. So, a semi bulk approach is utilized in which the conventional bulk material is replaced by a superlattice structure that is composed of multiple layers of GaN and InGaN. The indium composition in the InGaN quantum well is selected according to the output color. In the design phase, all parameters are selected from the most recent literature and LED technology is taken into consideration.

b) We will simulate our designed structure by SiLENSe software. SiLENSe is a software tool for 1D simulation of the active region of LEDs made of wurtzite III-nitrides (AlInGaN and ZnMgO). It can be used by both device and epitaxy engineers. Carrier transport model implemented in the software allows simulation of polar, semipolar, and nonpolar structures and accounts for specific features of nitride heterostructures including polarization effects, high density of threading dislocations and Auger recombination. The last one is responsible for the droop of internal quantum efficiency (IQE) observed in nitride LEDs at moderate and high current densities. SiLENSe provides distribution of critical parameters over the LED heterostructure, including partial (electron and hole) currents, electric field and potential, rate of carrier recombination, and carrier concentrations. Besides the physical parameters, we intend to find the terminal key factors like IQE, spectral response, wave function overlaps and IV characteristics

c) In our plan, we will also be exploring new materials suitable for LEDs. These materials are organic materials. We intend to produce these organic materials that are prepared by spin coater and spray pyrolysis coater. Then, it will be characterized by a source meter.

4. Project Description

4.1 A general background

Over the past few decades, III-nitride semiconductors have found the enormous influences in solid state lighting (SSL), power electronics and photovoltaics. Particularly, III-nitride based LEDs are fundamentally redefining the concepts of generation of light due to the superior material properties of direct bandgap and efficient light emission. Human eyes, in general, can detect the light emission with the wavelength from 360 nm to 770 nm, which is the visible light spectrum regime. The III-nitride semiconductor compounds of InGaN alloys have energy bandgaps covering from 0.7 eV (InN) up to 3.4 eV (GaN) with decreasing In-content from 100% to 0%, corresponding to emission wavelength from 365 nm to 1.77 μm, as shown in Figure 3 [4]. So, the InGaN material covers the whole visible spectrum regime, which is the primary motivation to pursue GaN based SSL [5-8].

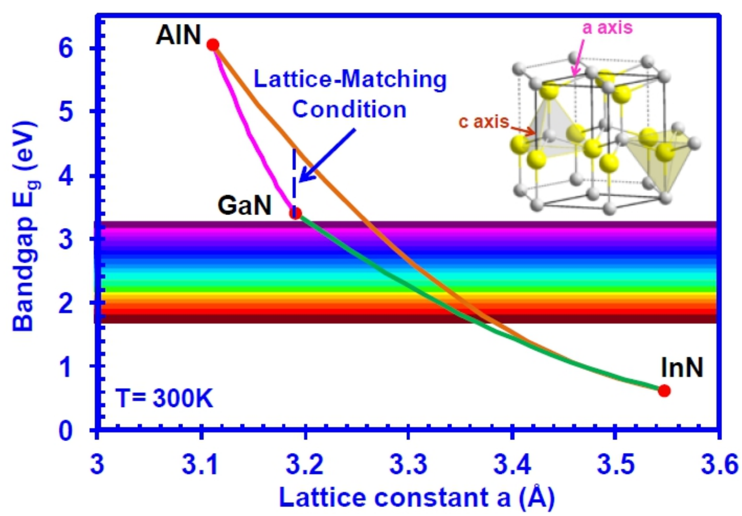

Fig. 3 Energy bandgap diagram and lattice structure of III-nitride semiconductors.

To get the best color output from a LED, an ideal structure would use many quantum wells to maximize the probability of radiative recombination [8]. Unfortunately, more quantum wells lead to a larger internal resistance of the structure. Accordingly, a design decision is made to work with a three quantum well structure. Table 1 describes all the required material properties of Wurtzite InN and Wurtzite GaN [9].

Table 1 Material Properties and values at 300 K.

Property	InN	GaN
Lattice Constant	3.533 Å	3.186 Å
Band Gap	0.65 eV	3.39 eV
m_e^*	0.11 m_o	0.2 m_o
m_h^*	1.63 m_o	0.8 m_o
Mobility	250 $cm^2.V^{-1}.s^{-1}$	440 $cm^2.V^{-1}.s^{-1}$
Radiative Recombination Coefficient	2×10^{-10} cm^3/s	1.1×10^{-8} cm^3/s

For ease of calculations and simulations, the width of the quantum well is fixed to 2.5 nm. This constrains the "tunability" of the structure in the long run, but aids in finding the material properties. The energy in one photon of light is related to the wavelength by,

$$E\,(eV) = \frac{1240\,(nm\,eV)}{\lambda\,(nm)} \tag{2}$$

λ is the wavelength.

Using Eq. (2), the energy in a photon of yellow light for instance (assuming wavelength of 580 nm) is 2.14 eV, while the energy in a photon of blue light (assuming wavelength of 470 nm) is 2.64 eV. The bowing parameter (b) of InGaN is -1.640 eV [10]. Using the material values presented in Table 1 and Eq. (3) for Vegard's Law, it is possible to find the In composition (*x*) required for blue and yellow emission.

$$E_{InGaN} = x\,E_{InN} + (1–x)\,E_{GaN} – b\,x\,(1–x) \tag{3}$$

The energy of the allowed levels in a quantum well is given by Eq. (4) for an infinite quantum well, where *h* is Planck's constant, *n* is the integer level, m* is the effective mass of the carrier and *L* is the width of the quantum well.

$$E_n = \frac{n^2 h^2}{8m * L^2} \tag{4}$$

This energy adds to the band gap energy for the actual transition experienced. These levels are present for both holes and electrons. Luckily, the energy values gained from this expression are larger than the actual energy shift in a finite quantum well. Due to the blue shift, caused by the recombination from higher energy levels in the conduction and valence band of each quantum well, the actual amounts of Indium should be increased [10].

Further, quantum barriers are important since carriers prefer to recombine by releasing the least amount of energy. Insufficient barrier thickness will not confine carriers in the well. The quantum barriers between each well will be about 10 nm thick which provides sufficient confinement.

For the ease of simulation, the band shrinkage due to doping was not considered by the SiLENSe software. Therefore, an equal doping of 1×10^{19} cm^{-3} holes was set on the p-side and 1×10^{19} cm^{-3} electrons was set on the n-side.

4.2 OLED configuration and operation

An OLED has an organic EL medium consisting of extremely thin layers sandwiched by two electrodes. In a basic two-layer OLED structure, one organic layer is specifically chosen to transport holes and the other organic layer is specifically chosen to transport electrons. The interface between the two layers provides an efficient site for the recombination of the injected hole–electron pair and resultant electroluminescence. Figure 4 shows a typical bi-layer OLED structure and the thicknesses of different layers.

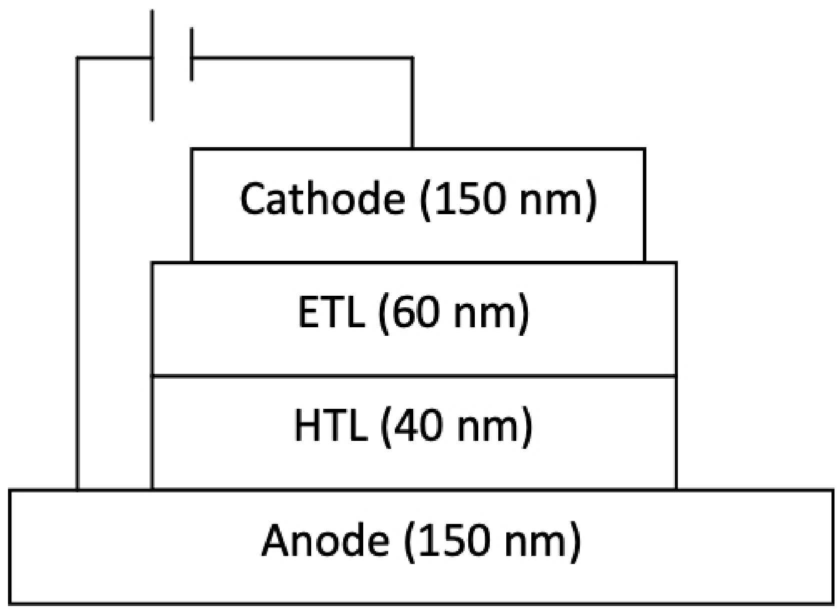

Fig. 4 A typical bilayer OLED.

When an electrical potential difference is applied between the anode and the cathode such that the anode is at a more positive electrical potential with respect to the cathode, injection of holes occurs from the anode into the highest occupied molecular orbital (HOMO) of hole-transport layer (HTL), while electrons are injected from the cathode into the lowest unoccupied molecular orbital (LUMO) of electron-transport layer (ETL) (refer to appendix for HOMO and LUMO). Holes are transported via hopping transport within HTL until they reach the ETL interface, where they build-up at the band edge mismatch. Simultaneously, electrons injected into the ETL are transported via hopping transport to the same heterojunction, where they also accumulate.

Statistically, a fraction of the built-up holes or electrons can cross the heterojunction interface leading to the creation of tightly bound electron-hole (e-h) pairs on individual molecules of either the HTL or the ETL. These tightly bound e-h pairs are referred to as excitons and may be thought of as single particles. They can relax either radiatively, emitting light characteristic of the optical band gap of whichever material that they were residing on, or non-radiatively, losing the energy as heat. In a two-layer device, all the excitons will transfer their energy to the ETL molecules prior to relaxing, and hence, no HTL emission will be observed.

The heterojunction should be designed to facilitate hole-injection from the HTL into the ETL and to block electron injection in the opposite direction in order to enhance the probability of exciton formation and recombination near the interface region. As shown in Figure 5, the HOMO of the HTL is slightly above that of the ETL, so that holes can readily enter the ETL, while the LUMO of the ETL is significantly below that of the HTL, so that electrons are confined in the ETL. The low hole mobility in the ETL causes a build-up in hole density, and thus enhances the collision capture process. Furthermore, by positioning this interface at a sufficient distance from the contact, the probability of quenching near the metallic surface is greatly reduced.

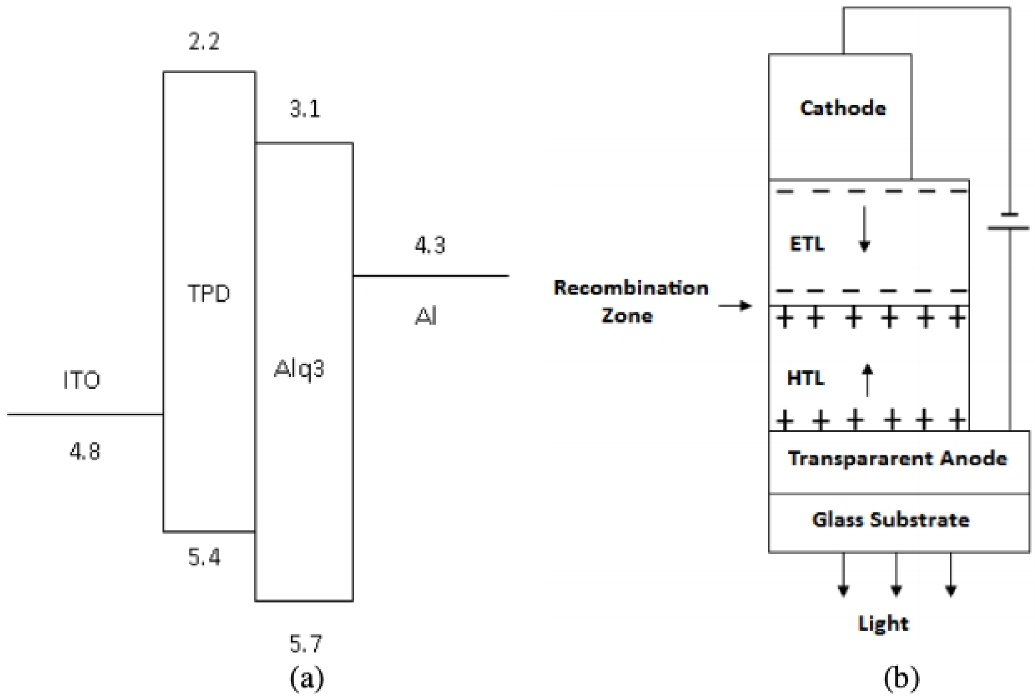

Fig. 5 a) Energy level diagram and b) Operation of a bi-layer OLED.

The simple structure can be modified to a three-layer structure, in which an additional luminescent layer is introduced between the HTL and ETL to function primarily as the site for hole–electron recombination and thus electroluminescence. In this respect, the functions of the individual organic layers are distinct and can therefore be optimized independently. Thus, the luminescent or recombination layer can be chosen to have a desirable EL color as well as high luminance efficiency. Likewise, the ETL and HTL can be optimized primarily for the carrier transport property.

The extremely thin organic EL medium offers a reduced resistance, permitting higher current densities for a given level of electrical bias voltage. Since light emission is directly related to current density through the organic EL medium, the thin layers coupled with increased charge injection and transport efficiencies have allowed acceptable light emission to be achieved at low voltages.

4.3 The project targets

The project targets can be put in two categories:

Category 1: Design and simulation of different color LED structures using GaN technology. In this regard, the LED will be designed based on the SB approach in order to enhance the relaxation inside the quantum wells. The target is to output a fixed wavelength w.r.t current injection to a high extent. The IQE of the different LED structures will also be traced. Some design ideas will be conducted to try to minimize the efficiency droop that results at high injection current. A proposed barrier design can be utilized to mitigate the efficiency droop. This could be constructed by using of large band gap thin barrier, for instance, AlGaInN or AlInN, sandwiching the InGaN QWs for increasing the effective barrier heights, reducing carrier leakage, and suppressing the efficiency droop issue.

Further, the low radiative efficiency and light output power of InGaN QW LED emitting at green and yellow spectrum region leads to the green gap issue of SSL. The severe charge separation issue of conventional InGaN QWs results in a low electron-hole wave function overlap and thus low radiative recombination rate. The QW structure engineering of introducing an energy local minimum inside the InGaN QW, specifically by linearly shaped staggered InGaN QWs and InGaN-delta-InN QWs, would shift the electron-hole wave function towards the center of active region.

Category 2: Fabrication and characterization of organic materials that are suitable for LED application. In order to get a high quantum efficiency for electroluminescence, it is necessary to achieve three attributes: efficient charge injection from the electrodes at low drive voltage, good charge balance, and confinement of the injected charge carriers within the emitting layers. The purpose of this part is to fabricate, measure and analyze OLEDs based on these fundamental principles using different cathode materials, injection layers and buffer layers in order to determine the best possible configuration. Starting from a simple bi-layered device, multilayered heterojunction OLEDs will be built by employing energy band engineering.

5. Research Design and Methods

We intend to carry out our simulation of the LED structures by SiLENSe software. SiLENSe is a software tool for 1D simulation of the active region of LEDs made of Wurtzite III-nitrides. Our choice for this software is based on its popularity and effectiveness in simulating LED structures [11-23]. It is widely used to investigate novel LED structures with different techniques regarding the well or barrier doping, thickness, In-composition, bulk type, relaxation percentage and other materials and physical parameters. The SiLENSe provides the following characteristics of an LED heterostructure:

- Band diagram of an LED at various biases,
- Distribution of electron and hole concentrations in the device structure,
- Electric field distribution,
- Radiative and non-radiative recombination rates,
- Dependence of the current density on the p-n junction bias (I-V curve),
- Internal quantum efficiency (IQE) dependence on the current density,
- Wave functions of electrons and holes in quantum wells,
- Emission and gain spectra of individual quantum wells and the whole structure,
- Waveguide modes (TE and TM) of an edge-emitting laser diode,
- Threshold current and power-current characteristic of an edge-emitting laser diode.

The above information forms a good basis for the LED structure optimization and for development of new light emitting devices. Moreover, the SiLENSe software has a friendly graphical user interface (GUI) designed to minimize user efforts needed to start simulations. Interactive visualization of the calculation results provides an excellent representation of the LED operation. The results can be also exported for visualization in external viewers. Figure64 summarizes the process flow of the simulation technique.

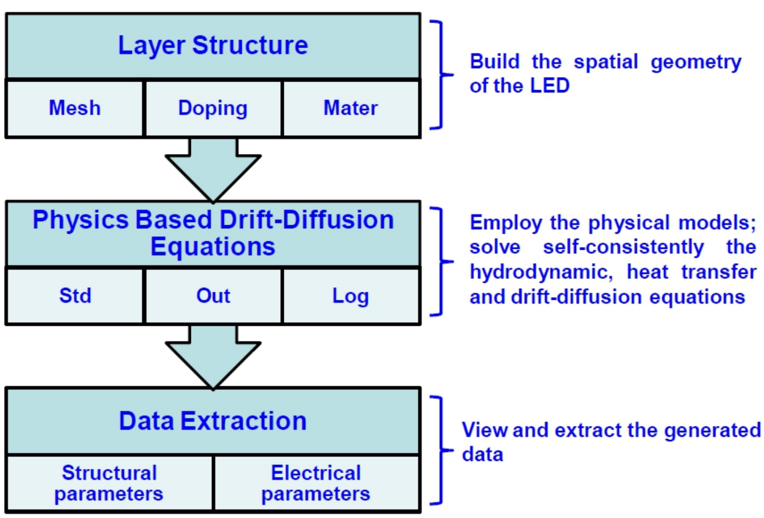

Fig. 6 The process flow of numerical simulation carried out by SiLENSe.

Some results of simulations are shown of a blue MQW LED structure consisting of n-GaN contact layer (Nd = 3×10^{18} cm^{-3}), an undoped InGaN SQW active region 3.5 nm thick, a p-type 10%-AlGaN electron blocking layer (Na = 7×10^{19} cm^{-3}), and a p-GaN contact layer (Na = 7×10^{19} cm^{-3}). The main structure is shown in Figure 7. Some results are collected in Figure 8.

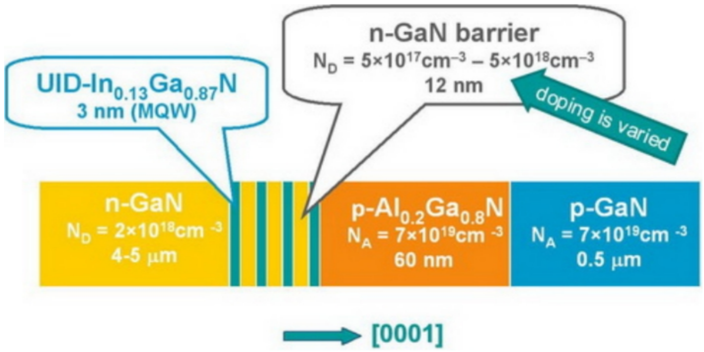

Fig. 7 Schematic view of the blue LED.

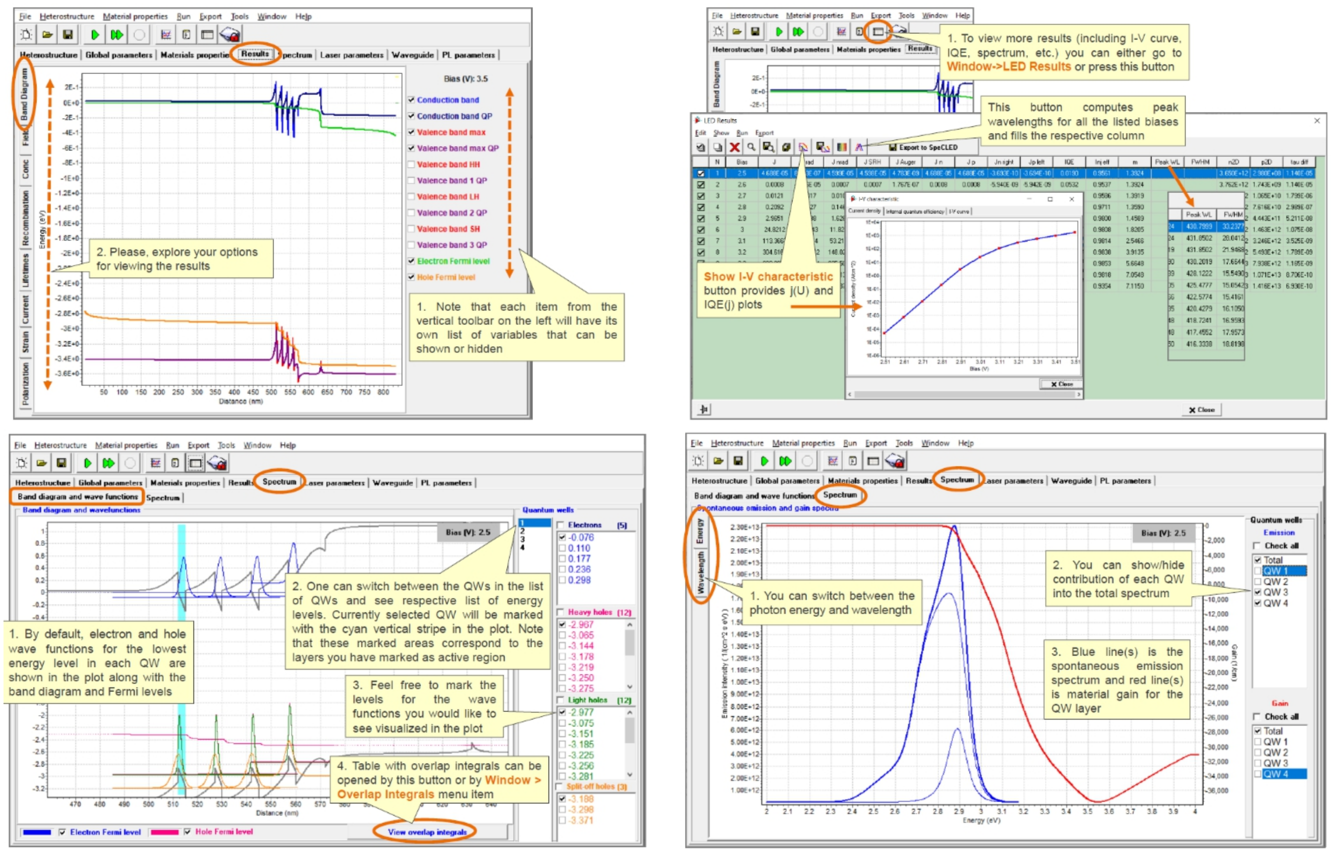

Fig. 8 Some results from SiLENSe showing the variation and flexibility of results overview and handling capabilities.

6. Anticipated Results and Evaluation Criteria

6.1 Design and simulation of inorganic GaN-based LEDs

Based on some fabricated LED structures, we will design and simulate different LED architectures to produce different colors using GaN technology and SB approach. The IQE of these LED structures will also be investigated thoroughly to study the impact of wavelength on the degradation of the efficiency. Some design ideas will be conducted to try to mitigate the efficiency droop. We aim to get clues about this phenomenon based on the SiLENSe simulation and try to find a solution that could be implemented practically. Further, we intend to study the green gap issue and try to find solutions like the linearly shaped staggered InGaN QWs and InGaN-delta-InN QWs that would shift the electron-hole wave function towards the center of active region which results in enhancing the radiative recombination.

The criteria to evaluate the performance of our LED structures will include a set of key factors that determines the LED output. Some of these are the IV characteristics, output power vs current, and internal quantum efficiency. Regarding the IV characteristics, it is required to minimize the turn-on voltage to decrease the electrical operating power. For the output light power, it is mandatory to increase this power. Many LEDs will operate at currents of around 20 mA, but the light output of an LED increases with increasing current. The IQE determines the most crucial output as it indicates how the LED will degrade when injected. The decline of IQE for high current injection (droop) is undesirable. Decreasing the droop is the main measure factor of success of our design ideas.

6.2 Fabrication and characterization of organic materials dedicated for LEDs

Many obstacles must be overcome before the potential of OLED technology can be fully realized. These include: Device Stability, the voltage needed to provide adequate current in direct drive pulsed mode, Fine Patterns with vivid colors, Light Extraction, and Fabrication Costs.

• Device Stability: OLEDs have relatively short lifetime. Exposure to humidity and heat can be particularly damaging to these devices. Although encapsulation can reduce the impact of hostile environments, it is still difficult to preserves the advantages of low weight, thin profile and flexibility. The performance of the device must not deteriorate markedly with age, either through extended storage or operation. Differential aging between the RGB pixels, or between pixels that are used at different frequencies, must be kept low.

• Voltage: The voltage needed to provide adequate current in direct drive pulsed mode is too high for inexpensive CMOS electronics and efficient operation. For active-matrix devices, drift in threshold voltages can lead to loss of control in operation, and so must be minimized or compensated for.

• Fine patterns with vivid colors: Human perception of luminous intensity peaks sharply in the green, making blue and red devices much more difficult to create at the same efficiency. Although great progress has been made with respect to the active organic materials, better blue, green and red emitters are needed to establish clear superiority over the competing technologies.

• Light extraction: With the present planar structures, most of the light emitted by the organic molecules remains trapped in the diode and does not reach the viewer. An easily manufacturable structure is needed that directs more light forward without increasing the reflection of ambient light.

• Fabrication costs: Fabrication cost must be reduced so that OLED technology can compete with more mature and well developed technologies.

7. Expected Project Outcomes and Impact to AASTMT

I- Technical output and Impact:

a. Design and simulation of different color LED structures using GaN technology.
b. Fabrication and characterization of organic materials that are suitable for LED application.
c. TSPC gives inspiration about possible M.Sc. thesis.

II- Financial feasibility & Socio-economic Impact:

a. Explore new optical materials which can play a role in the fabrication of organic Light emitting diode.

III – Publication:

a. Publish at least one research paper in a Q1-Q2 journals or its equivalent.

8. Resources

Resources are divided into the following parts:

I. Laboratory space: we will need about two types of labs.
   a. Electronics Lab: normal electronics lab equipped by source meter, one function generator, personal computer and printer. This lab is normally available in AASTMT Cairo campuses. However, spin coater and spray pyrolysis are not available in AASTMT campuses. Spin coater is engineered to provide a high level of rotation accuracy allow for the uniform application of polyimides, metal-organics, dopants, most organic solutions. Spray pyrolysis is required to have additional coating capacity.
   b. Physics Lab: normal physics lab equipped by spectrometer which is available in AASTMT Cairo campus.
   c. Simulation package from SiLENSe: With this package, InGaN/GaN/InGaN multi quantum well (MQW) structures can be investigated

II. Major equipment:
   1. Source meter
   2. Spin coater
   3. Spray pyrolysis
   4. Spectrometer
   5. SiLENSe simulation package

III. Personnel:
   1. Electronics technician: to carry out the technical work.

9. Team Information

Eng. Basma Ahmed

Eng. Basma is currently studying a M.Sc. in Electronics and Communications Engineering at the College of Engineering and Technology, Arab Academy for Science, Technology and Maritime Transport (AASTMT). Eng. Basma obtained her B.Sc. degree in Telecommunications Engineering at Egyptian Russian University in Egypt. She is working now as teaching assistant at Telecommunications Engineering in Egyptian Russian University

Dr. Ahmed Ramzy

Dr. Ahmed is currently a Researcher in Electron Microscope & Amplifier, Thin Films Department, Physics Research Center, National Research Center.
B.Sc. (2005) in Physics – Faculty of Science- Mansoura University.
M.Sc. (2010) in Solid State Physics – Faculty of Science- Mansoura University.
Ph.D. (2016) in Solid State Physics – Faculty of Science- Ain Shams University
Experience in preparation thin films such as (photo voltage cell, photodetectors, solar cell by (Thermal Evaporation, Spin Coating, Spray Pyrolysis, and Chemical Bath Deposition)

Assoc. Prof. Ahmed Shaker

Ahmed Shaker received the M.Sc. and Ph.D. degrees from Ain Shams University, Cairo, in 2003 and 2010, respectively. Since 1997, he has been with the Engineering Physics Department, Faculty of Engineering, Ain Shams University, where he is currently an Associate Professor. Recently, he joined the Electrical and Computer Engineering (ECE) Department, North Carolina State University (NCSU), Raleigh, USA, as a Postdoctoral Researcher, where he is involved in solar cell and GaN-based LEDs fabrication and modeling. His research interests include simulation and modeling of semiconductor power devices, solar cells, 3D detectors, and nanoscale devices, including TFETs and CNTFETs.

Assoc. Prof. Mostafa Fedawy:

Dr. Mostafa Fedawy finished his B.Sc. and M.Sc. at the Electronics and Communications Department, College of Engineering, Arab Academy for Science, Technology and Maritime Transport, Egypt, at 2001, 2006, respectively. Dr. Fedawy finished his Ph.D. at Ain Shams University, Egypt, 2013 in the field of Devices and Nanotechnology. He is currently an Associate Professor at Electronics and Communications Department, College of Engineering, Arab Academy for Science, Technology and Maritime Transport, Egypt.

His research interests include, photovoltaic devices, optoelectronics devices, sensors, simulation and modeling of nanoscale devices including graphene transistors, TFETs and CNTFETs.

Prof. Mostafa Hussein

Moustafa H. Aly received his B.Sc., M.Sc. and Ph.D. from Faculty of Engineering, Alexandria University, Alexandria, Egypt, respectively in 1976, 1983 and 1987. He is a professor of Optical Communications, Electronics and Communications Engineering Department, College of Engineering and Technology, Arab Academy for Science, Technology and Maritime Transport. Currently, he is the president consultant in Alamein Campus, Egypt. He was a co-supervisor of 140 M.Sc. and Ph.D. students and published more than 300 journal and conference papers. His research area includes Optical Communications, Optical Amplifiers, Free Space Optics, Visible Light Communications, and Optical Networks.

Research Team Information Table

Name of Res. Team Member in English	Name of Res. Team Member in Arabic	University / Institute In English	Position /Title	% of time spent on project	No. of months	Incentive per month (LE)	Number of other projects and their IDs	Total % of time spent on other projects	Contact No.
Mostafa Hussein Aly	مصطفى حسين علي	AASTMT (PI)	Prof.	20%	6	1700	-	-	01006639473
Mostafa Hassan Fedawy	مصطفى حسن فداوي	AASTMT	Assoc. Prof.	20%	6	1700	1 ID:2056	30%	01093738861
Ahmed Shaker	أحمد شاكر	ASU	Assoc. Prof.	20%	6	1700	-	-	01222481434
Ahmed Ramzy	أحمد رمزي	NRC	Assis. Prof.	20%	6	1700	-	-	01008910644
Basma Ahmed	بسمة احمد	ERU	Eng.	20	6	1700	-	-	01000275839

10. Project Management

Top Management committee of this project consists of ش general manager and two team coordinators. Also, according to teams needs, advisors and consultants will join this committee. Management, financial, solving some of technical problems, project orientation and cooperation of all project team members are the main objectives of this committee.

The first team is responsible for designing and simulation of inorganic GaN-based LEDs and the second is responsible for investigating the organic materials that dedicated for LEDs. Each of the two teams will share their information to maintain all project members with project target. Also team's coordinators will maintain the same objective and cooperation of team members.

The monitoring of the project activities will be delivered through a status and progress reports. A status report should be delivered each month, just to clear the status of the different activities. Its generation is synchronized with the monthly meeting of project group (to be discussed within the meeting). It should be composed of a maximum of one page containing: the red flags, the status of each activity (ongoing/on hold, terminated, etc…). A more detailed technical report should be delivered each 3 months during the project progress. In this progress report, the activity status is described in details with emphasis on the problems and the time monitoring. Finally, a complete report will be delivered at the end of the project.

On the other side, the quality control of the activity achievement could be evaluated using an activity planning sheet and a self-evaluation sheet. The first Activity Planning Sheet (APS) should clearly define, the required goal, the responsible team, the required resources, the time line, the intermediate decision points, and the expected expenses and should be filled at the beginning of any activity. The APS should state deliverables and their timing.

Each one of such sheets enables to control the quality of the jobs achieved. In addition to these sheets, questionnaires will be used in monthly meetings, to obtain the necessary feedback from the working teams. The outputs of the activities related to this part will thus be:

1. Evaluation sheets.
2. Progress reports.
3. Project final report.

11. Allowable Project Costs

11.1 Major equipment list

Items	Quantity	Estimated cost (LE)
SiLENSe software	1	80,000 LE
Spin coater	1	85,000 LE
Spray pyrolysis	1	33,000 LE
Total		198,000 LE

11.2 Eligible costs

Eligible costs	Break downs		AASTMT support (L.E.)
(A) Staff Cost	Prof. Mostafa Hussien- PI		10,200
	Name of each Team member Assoc. Prof. Mostafa Fedawy - **Project Coordinator** Assoc. Prof. Ahmed Shaker - **Team Coordinator**		 10,200 10,200
	Dr. Ahmed Ramzy- **Team Coordinator**		10,200
	Eng. Basma Ahmed- **Team Coordinator**		10,200
	Technicians and/or Labor		5000
	Consultation fees		0
	Total		56,000
(B) Equipment	Equipment		198,000
	Spare parts		0
	Total Equipment		198,000
(C) Expendable Supplies & Materials	Stationary		0
	Miscellaneous Laboratory, Field supplies, Materials		20,000
	Total expendable Supplies & Materials		20,000
(D) Travel	Internal Transportation		0
	Accommodation		0
	Total travel		0
(E) Other Direct Costs	Services	Manufacture of specimens & prototypes	0
		Acquiring access to specialized reference sources databases or computer software	0
		Computer services	0
	Report preparation		2,000
	Publications & patent costs		8,500
	Workshops organization or Training		0
	Others[1]		3500
	Total other direct costs		14,000
(G) Total Costs			**288,000**

[1] Internal Transportation

12. Plans for Disseminating Research Results

The results produced are to be reviewed monthly by the principal investigator to be evaluated. Initial promising results will be put in the form of a conference article. The main outcome is expected to be published in a peer reviewed journal.

The approach of publishing the work will be similar to our recent publications. We do not expect any data to be kept confidential.

12.1 Project Plan

12.1.1 Tasks and activity codes

Code	Main Tasks
T1	Preparation
T2	Design
T3	Simulation
T4	Implementation
T5	Characterization
T6	Publication
T7	Documentation

Code	Activity
A01	Survey
A02	Design
A03	Simulation
A04	Purchase the equipment
A05	Synthesize the new material
A06	Material characterization
A07	Publication
A08	Documentation

12.1.2 A Detailed plan on project's activities (GANTT CHART)

Activity Name	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
1. Preparation												
1.1 Survey	A01	A01	A01									
2. Design												
2.1 Design			A02	A02	A02							
3. Simulation												
3.1 Simulation			A03	A03	A03	A03						
4 Implementation												
4.1 Purchase the equipment	A04	A04	A04									
4.2 Synthesize the new material				A05	A05	A05	A05					
5. Characterization												
5.1 Material characterization						A06	A06					
6. Publication												
6.1 Publication							A07	A07	A07	A07		
7. Documentation												
7.1 Documentation											A08	A08

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14. Declaration of Original Submission and Other Grant(s)

By signing below, I acknowledge that I have read, understand and accept to comply with all the terms of the foregoing application, mentioned in AASTMT general conditions and guidelines for submitting a research proposal, including, but not limited to:

- The total number of the application pages should not exceed 30 pages excluding a cover page, as well as all sections of the proposal (as mentioned in AASTMT General Conditions and Guidelines for Submitting Research Proposal).
- At any time, a contracted AASTMT project team member should only be participating in a maximum of one project.
- Allowable budget maximum limit should be strictly adhered to in the project proposal. In all cases, requested budget has to be justified in detail.
- AASTMT guidelines, IPR rules, code of ethics, etc. (www.aast.edu), should be read carefully and adhered to. These are integral parts of the contract.
- All proposals – in addition to PI and other data - must be uploaded to the AASTMT website by the designated deadline. Uploaded PI data should conform to the corresponding data in the application form.

Applications will not be considered eligible and will be discarded in the following cases:

- Proposals submitted by e-mail or sent as hard copies or uploaded to the AASTMT website after the deadline.
- Proposals not conforming to the designated format.
- Proposals whose uploaded PI data does not conform to PI data in the proposal file.
- Proposals in which the allowable budget maximum limit has been exceeded.
- Proposals in which maximum allowable contracted AASTMT project participation limit has been exceeded.
- Proposal letter does not include a scanned copy of the signed and stamped PI institution endorsement letter in case of team member work outside AASTMT.
- Proposal does not include a scanned copy of the signed acknowledgment form.

Date & Signature: Mostafa Hussein ______________________