An Advanced Study on Ultraviolet Gain Characteristics of AlGaN/AlN in Nanotechnology

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Abstract- *This research work has been aimed to investigate an advanced study on Ultraviolet Gain Characteristics of advanced material AlGaN/AlN based hetero-nanostructure for various applications of purification and sterilization for today's society in emerging technological nanophysics. In this research work, with the help of theory of effective masses of SM (Single and Multi) bands, the various appropriate UGPs (Ultraviolet Gain Parameters) have been computed simulatively. The behaviours of spectral performances of intensities of UV gain (in cm^{-1}) with wavelengths (in nm) for AlGaN/AlN have been investigated by optimized techniques. This type of research work also provides the proper information about the modal confinement value of UV gain intensities (in cm-1) with several values of densities of carriers per unit volume (in cm-3) have been simulated and calculated systematically. In appropriate computational results, the crest value of UV gain intensities (~ 1751 cm-1) has been achieved at the specific wavelength ~ 254 nm. Hence, the utilities of this UV-light of wavelength ~ 254 nm have played a substantial role in the purification and sterilization applications in today's society. Moreover, the UV-lights of wavelength ~ 254 nm have also extensively been used in better purification to disinfect the surfaces, air and water by eliminating the various types of viruses, bacterias and harmful contaminants.*

Keywords: UV gain, Differential UV gain, Modal confinement UV gain, UGC, UGP, AlGaN, AlN

Introduction

Since the last few years' heterogeneous nanostructure based various optical devices using UV light are being utilised in the various fields such as medical and industrial. The heterogeneous nanostructures such as AlGaN, AlGaInAs, AlGaInN, AlAsInP, GaAsAl, and GaAs have vital roles in recent time due to fabulous applications in various fields such as in medical research area, industrial field, area of remote sensing, aerospace field, SIL (Shortwave Infrared Light) emitters, SIL lasers, SIL detectors, and SIL communications by GFOCs nanosystems etc. In emerging Nanotechnology based photonics, the various EO characteristics of III-V material based heterogeneous nanostructures [1-7] have been simulated and investigated experimentally and theoretically by the researchers in recent time. The material InAlGaAs/InP based heterogeneous nanostructure provides a fabulous role in the SIL emitters due to their higher temperature tolerance performances because of this type photonic material has higher energy values of CBOs (Conduction Band Offsets) than VBOs (Valence Band Offsets) so elections have been confined properly hence leakage property provides negligible under the process of vaporisation at higher thermal conditions. This III-V group materials InAlGaAs and InAlAsN based heterogeneous nanostructure have fabulously been utilised in NL (Near-infrared Light) applications because of that the emitted NL has been highly safe of our eyes and all type effects of dispersions and scattering are negligible in the lasing process. The various EO characteristics [8-10] of MQL (Multi Quantum-well Laser), BTL (Bipolar Transistor Laser) and JDL (Junction Diode Laser) based on III-V material AlGaInAs-InP have recently been investigated by the several authors. In this work, the behaviours of spectral performances of intensities of UV gain (in cm^{-1}) with wavelengths (in nm) and energies (in eV) of lasing photons for AlGaN/AlN have been computed by simulation techniques. This type research work also provides the proper information about the performance of peak value of intensities of net UV gain, differential value of UV gain intensities (in cm^2) and various values of parameters of anti-guiding factor with densities of carriers per unit volume (in cm^{-3}). Further, in this study, the modal confinement value of UV gain intensities (in cm^{-1}) and peak UV gain with several values of current densities per unit area of cross section (in Acm^{-2}) have been simulated and calculated systematically. In appropriate computational results, the crest value of UV gain intensities (~ 1750 cm^{-1}) has been achieved at the specific wavelength ~ 254 nm.

Computational and Theoretical Details

By taking into account the various dimensional performances of nanoscale type structure, the simulative type heterogeneous nanostructure has been proposed by Nano technological computing. The proposed heterogeneous interface nanostructure is a simulatory type structure and it has total five RNLs (Refractive-index Nanoscale Layers) in which one QNL (Quantum-well Nanoscale Layer) is sandwiched between two RNBLs (Refractive-index Nanoscale Barrier Layers) hence this simulated system is enveloped by two RNCLs ((Refractive-index Nanoscale Cladding Layers), such that the whole system has been grown simulatively on substrate of AlN layer. The entire details of compositional and dimensional parameters have been illustrated by following table 1.

Table 1: The details of parameters of simulatively proposed heterogeneous interface based nanostructure.

Five types of specified RNLs	**The value of composition x for specified RNLs ($Al_xGa_{1--x}N$)**	**Values of thickness of specified RNLs in (nm)**	**Values of Photon's wavelength in (nm)**	**Energies values of BOs in (eV)**
RNCL(C.B.)	0.526	10	209	0.2356
RNBL(C.B.)	0.431	5	235	0.1625
QNL	0.312	6	260	0.0614, - 0.0614

RNBL(V.B.)	0.431	5	235	- 0.1625
RNCL(V.B.)	0.526	10	209	-0.2356

In order for longer confinement of energy envelope wave functions, the higher values of CBOs and VBOs have been required. The values of QCF (Quantum-well Confinement Factor) have been influenced by confinement of energy envelope wave functions. The QCF inspired enhancement of UV gain is termed as modal confinement UV gain. The OCs (Optical Characteristics) of several types of intensities of gains such as strain influenced NL gain, A-G factor inspired light gain and electrochemical affected optical type gains etc. [11-14] have been optimised due to their substantial type unique light performance. Basically, the intensity of UV gain depends on the nature of materials as well as heating effect, internal and external strain effects and NWTLs. Thermal effect and NWTLs influenced UV gain expression as a function of photon's energies is explained by Chuang [15], which is given by the following equation: -

$$G(h\nu) = \frac{q^2 h}{2n_{eff} h\nu m_0^2 \varepsilon_0 c} \times \left[1 - \exp\left(\frac{h\nu - \Delta f}{k_b T}\right)\right]$$
$$\times \sum_{nc,nv} \frac{|M_b|^2 f_c f_v}{4\pi^2 L_W} \times \frac{(h/2\pi\tau) dk_x dk_y}{\pi(\{h\nu_{nc} + h\nu_{nv} + h\nu_{sg}\} - h\nu)^2 + (h/2\pi\tau)^2}$$

The frequencies of relaxation oscillation in terms of several parameters [16-21], such as Antiguiding parameter, differential UV gain parameter, and peak UV gain parameter etc. have been simulated and investigated by most of the researchers. The frequency relationship of ROs in terms of differential type UV gain has been given by the formula :-

$$f_r = \frac{1}{2\pi} \times \left(\frac{(cP)}{(n\tau_p)} \times \{G^{'}(h\nu, N)\} \right)^{1/2}$$

Analytical Results and Discussions

Nanoscale type heterogeneous structures have been found by the proper combination of multiple type heterogeneous interfaces. The heterogeneous type interfaces have better performances than that of the homogeneous type interfaces in the nanoscale technological and engineering fields. The various types of ERs (Electromagnetic radiations) such that, SIR (Shortwave Infrared Radiation), NR (Near-infrared Radiation), and UVR (Ultraviolet Radiation) have been emitted by heterogeneous nanostructures and these have been used in various optical devices. The enhancement study of knowledge of NL optical gain [9, 10] has a substantial role in the explanation of NL characteristics. However, UVL gain as well as NL gain has been occurred by the process of simulated emission in the lasing process. The condition in which the performance value of rate of simulated emission is obtained greater than value of absorption rate then intensity of UV gain enhancement has been achieved. The spectral behaviours of performances of enhancement in intensities of UV gain (in cm^{-1}) with wavelength (in nm) of lasing photon and net peak modal confinement intensities of UV gain (cm^{-1}) with densities of carriers' concentrations ($\times 10^{18}$ cm^{-3}) for AlGaN/AlN heterogeneous type nanostructure have been illustrated in fig 1.

The blue graph here shows the variation in net peak modal confinement UV gain with densities of carriers' concentration ($\times 10^{18}$ cm^{-3}) and it has also been noticed that net peak modal confinement UV gain has approximately proportional behaviour with carriers because of enhancement in energies values in separations of quasi type Fermi levels for CB and VB offsets. In fig 1,by blue graph, it has also been predicted that in starting at the lowest value of densities of carriers' concentrations ($\times 10^{18}$ cm^{-3}) at which the value of net peak modal confinement UV gain obtains approximately negligible is called transparency density of carriers. However, the value of net peak modal confinement UV gain in blue graph has been saturated at higher value of carriers due to various phenomena of burning of special and spectral holes. Further, in fig. 1 the black curve shows the spectral behaviours of UV gain with wavelength in lasing condition and the crest value of UV gain is achieved at the wavelength of 254 nm in the range of UV spectra (~ 225 nm to 270 nm). This type of UV light has very important contribution in the nanotechnological bio sciences. The UVL of wavelength range is approximately equal to 254nm has very crucial role in the proper purification of water in recent life. Next, in simulatory results, the crest value of UV gain intensities (~ 1750 cm^{-1}) has been achieved at the specific wavelength ~ 254 nm. Hence, the utilities of these UVLs of wavelength ~ 254 nm have played a substantial role in the purification and sterilization applications in recent life. Moreover, the UVLs of wavelength ~ 254 nm have also been utilised in the high purification to disinfect the surfaces, air and water by eliminating the various types of viruses, bacterias and harmful contaminants in different areas such as technological engineering and medical nanosciences.

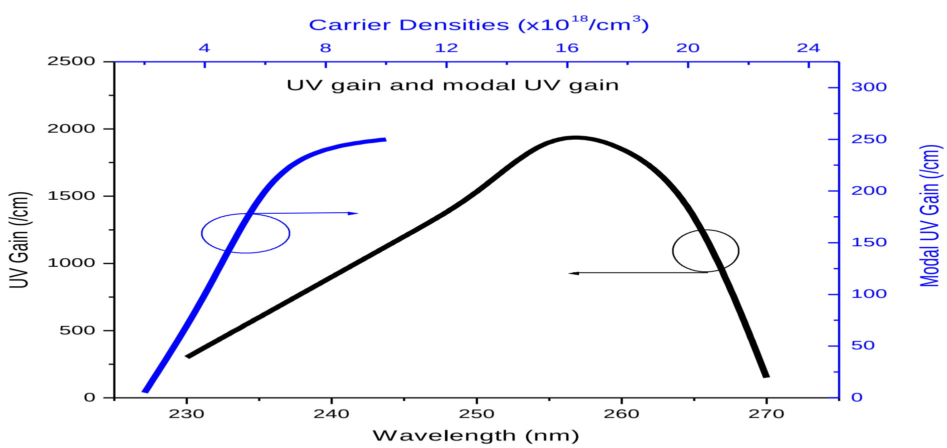

Fig:1. The graphical behaviours of performances of intensities of UV gain enhancement (in cm^{-1}) with wavelength (in nm) of lasing photon and net peak modal confinement intensities of UV gain

(cm^{-1}) with densities of carriers' concentrations ($\times 10^{18}$ cm^{-3}) for AlGaN/AlN heterogeneous type nanostructure.

The change in intensities of UV gain with respect to densities of carriers is said to be the differential value of UV gain. The spectral behaviours of performances of intensities of UV gain enhancement (in cm^{-1}) with energies (in eV) of lasing photon and differential type intensities of UV gain enhancement (cm^{-1}) with densities of carriers concentrations ($\times 10^{18}$ cm^{-3}) for AlGaN/AlN heterogeneous type nanostructure have been illustrated in fig. 2. In the RHS of fig. 2 the spectrum of UV gain in black colour has been shown with energy of photons and it has also been cleared by UV gain spectrum that the crest value of UV gain (~ 1750 cm^{-1}) has been found at ~ 4.8 eV of photon energy. Although, in the LHS of fig. 2 the differential UV gain in blue colour has been shown with carriers and it has also been cleared by blue graph that the differential UV gain has inversely behaviour with carriers, that is the differential value of UV gain has been found to diminish as enhance in carriers because of the rate of change in UV gain is less than the rate of change in carriers at higher value of carriers.

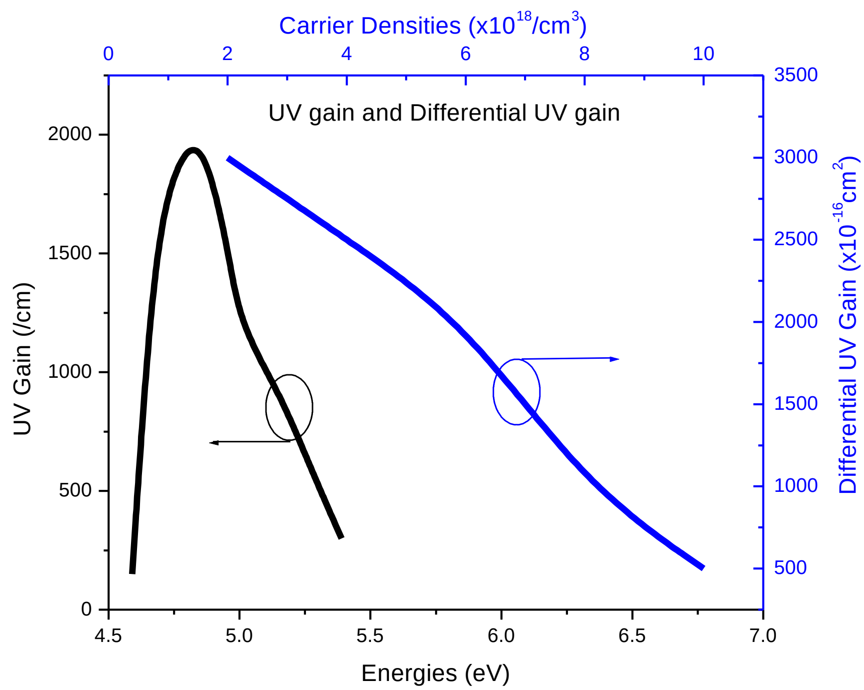

Fig: 2. The spectral behaviours of performances of intensities of UV gain enhancement (in cm^{-1}) with energies (in eV) of lasing photon and differential type intensities of UV gain enhancement (cm^{-1}) with densities of carriers concentrations ($\times 10^{18}$ cm^{-3}) for AlGaN/AlN heterogeneous type nanostructure.

Conclusions

Under various types of heterogeneous nanostructures based nanotechnologies, this type of work provides a substantial and critical contribution in the simulatory study on characteristics of UVLs emitted by AlGaN/AlN heterogeneous nanostructure for various applications of purification and sterilization. The behaviours of spectral performances of intensities of UV gain with wavelengths and energies of lasing photons for AlGaN/AlN have been computed by simulation techniques in this type of simulatory studies. This work also understands the proper information about the performance of peak value of intensities of net UV gain, differential value of UV gain intensities and various values of parameters of anti-guiding factor with densities of carriers per unit volume. Further, in this study, the modal confinement value of UV gain intensities and peak UV gain with several values of current densities per unit area of cross section have been simulated systematically. In the simulatory type computational results, the crest value of UV gain intensity (~ 1750 cm^{-1}) has been achieved at the specific wavelength ~ 254 nm. Such that, the utilities of this type UVLs of wavelength (~ 254 nm) have a fabulous role in the purification and sterilization applications in recent life. In addition, the UVLs of wavelength ~ 254 nm have also extensively been extensively used in the high purification to disinfect the surfaces, air and water by eliminating the various types of viruses, bacterias and harmful contaminants in bio based technological nanosciences

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