Studies on Reflectance-Temperature characteristics of AlGaN semiconductor at three communication windows

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Abstract. This paper reports the temperature variation of reflectance with respect to AlGaN waveguide structure. Plane wave expansion technique is employed for simulation to exhibit the reflectance pertaining to AlGaN waveguide structure. The simulation results show the approximate linear variation of reflectance with respect to temperature in the aforementioned AlGaN photonic waveguide structure at three communication windows (850 nm, 1310 nm, 1550 nm). Such characteristic study yields with accuracy, the realization of temperature dependence of reflectance.

Keywords: Plane wave expansion, AlGaN, Reflectance, Temperature

1. Introduction

In recent years, integrated photonics finds potential applications in non-linear photonic devices. The direct band gap Group-III Nitride semiconductors are promising non-linear materials for the development of optoelectronic devices. Being a wide band-gap semiconductor with significant optical properties, Aluminum Gallium Nitride (AlGaN) suitably falls into this category and it is a good candidate for optical communication and sensing applications [1]. To pertain to the wave-guide structures for communication purposes, different quantities like refractive index and temperature, exhibit significant roles in experiencing the optical features [2-3]. With respect to the reflectance that stands as a function of refractive index in wave guide structures, this study realizes the temperature impact on this wave guide structure by the use of reflected signals. Earlier works have linked up to simulation analysis for light waves reflected from polymer waveguide structures taking account of temperature realization which includes three polymer waveguide structures on Silicon substrate by considering one wave length of 1550 nm at temperatures ranging from 300 K to 400 K [4]. Literature study also finds GaN grating structure or waveguide structure at 700 nm wavelength of light taking into account absorption loss and transmitted energy post incidence of light wave [5]. Related works have also taken care of reflected energy dependence of temperature in connection with refractive index and thickness variations [6]. This current paper delves into the refractive index change with room temperature and above up to 550 K at an energy gap of 1.5 eV for AlGaN and leads to the characteristic analysis of shifting of reflectance at three communication windows [7]. The three communication windows we have opted for in this paper for the clarification of temperature...
dependence of reflectance are 850 nm, 1310 nm and 1550 nm. Consequently plane wave expansion (PWE) method has been incorporated to explore the reflectance loss in aforementioned photonic waveguide structure. Temperature variation affects different parameters, most significantly refractive index, and structure of material and thickness of waveguide. The thickness of the waveguide structure for different temperatures, ranging from 300K to 550K is kept constant at 92 nm. The variation of refractive index with temperature at the three wave lengths (850 nm, 1310 nm, 1550 nm) is given in Table-1. This current paper is lined up as follows; proposed AlGaN waveguide structure, simulation results, analysis and result discussion are presented in section-2. Ultimately conclusions are presented in section-3.

2. Structure, Analysis and Discussion
To realize this Reflectance-Temperature characteristic, we propose an experimental set-up to investigate this variation. The experimental arrangement is shown in figure 1.

![Experimental arrangement](image)

**Table 1: Refractive Indices at three communication windows with temperatures from 300 K to 550 K**

| Temperature in Kelvin | R.I. for 850 nm | R.I. for 1310 nm | R.I. for 1550 nm |
|----------------------|----------------|-----------------|-----------------|
| 300                  | 2.846          | 2.787           | 2.768           |
| 350                  | 2.849          | 2.789           | 2.77            |
| 400                  | 2.852          | 2.793           | 2.774           |
| 450                  | 2.859          | 2.799           | 2.78            |
| 500                  | 2.861          | 2.802           | 2.783           |
| 550                  | 2.864          | 2.804           | 2.785           |
Using data from Table-1 and employing PWE technique, simulation is done to find out reflectance of such waveguide with different temperatures varying from 300 K to 550K. The simulation results for temperature 300 K for 850 nm, 1310 nm, and 1550 nm are shown in figures 2(a)-(c) respectively. For other temperatures (350 K, 400 K, 450 K, 500 K, 550K) simulation is done as well, but results have not been shown here.

Figure 2(a): Reflectance variation with wavelength at temperature 300 K for wave length 850 nm

Figure 2(b): Reflectance variation with wavelength at temperature 300 K for wave length 1310 nm

Figure 2(c): Reflectance variation with wavelength at temperature 300 K for wave length 1550 nm.
The figures 2(a)-(c) represent the variations between Reflectance (Arbi. Unit) along the vertical axis against the wavelength (µm) along horizontal axis for 850 nm, 1310 nm and 1550 nm respectively. From these plots, it is observed that the variation of reflectance has an approximate linearity with these wavelengths. We have taken the measurement of reflectance at the three wavelengths that means 850 nm, 1310 nm, and 1550 nm in this paper.

Referring to these figures 3(a)-(c), the reflectances are 0.5759, 0.5669, and 0.5163 (Arbi. Unit) corresponding to wavelengths 850 nm, 1310 nm and 1550 nm respectively at 300K temperature. Similarly the reflectances for other temperatures are also calculated for the aforementioned waveguide structure. Attractive results have been observed that the reflectance for 850 nm increases linearly from 0.5500 to 0.5759 at temperature 300K-550K. Where in same waveguide structure, the reflectance decreases linearly with same temperature ranges. Using above values of reflectance for different temperatures at 850 nm, 1310 nm, 1550 nm, we plot their variations.

Finally three graphs have been plotted figures 3(a)-(c) with Temperature along horizontal axis and Reflectance along vertical axis corresponding to three wavelengths mentioned above.

For the wave length 850nm, the reflectance ranges from 0.5759 to 0.5775(Arbi. Unit), for the wave length 1310nm, the reflectance ranges from 0.5669 to 0.5721(Arbi. Unit) and for the wave length 1550nm, the reflectance ranges from 0.5163 to 0.5221(Arbi. Unit), corresponding to 300K-550K temperature ranges.

![Figure 3(a): Reflectance vs. Temperature for wave length 850 nm](image-url)
Figure 3(b): Reflectance vs. Temperature for wavelength 1310 nm

Figure 3(c): Reflectance vs. Temperature for wavelength 1550 nm
3. Conclusions

With the help of simulation studies, the variation of Reflectance with Temperature is thoroughly investigated in the aforementioned AlGaN waveguide structure. The simulation is done with plane wave expansion (PWE) method whose results depict that the reflectance has increasing linearity with temperature, ranging from 300 K-550 K for all the three communication windows (850 nm, 1310 nm, 1550 nm) with AlGaN waveguide structure of thickness 92nm. The trending linearity of approximately 96% is nicely verified with these results leading to an accurate demonstration of temperature in AlGaN waveguide structure at the aforementioned three communication windows.

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