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**ORIGINAL ARTICLE**

# Effect of Si-Doping Position on Optical Properties of Nitride Quantum Well

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**ABSTRACT**
*The effects of Si doping on the emission energy in a set of GaN/AlGaN multiple quantum well (MQW) samples with different position of the dopant layer were studied by means of photoluminescence (PL) measurements. When the doping is in the barrier and in both barrier and well, the MQW emission appears above the GaN band gap, while the sample doped in the well shows a redshifted emission. The redshift is attributed to the self-energy shift of the electron states due to the correlated motion of the electrons exposed to the fluctuating potential of the donor ions.*
*Keywords-: Emission energy, multiple quantum well, red shift, photoluminescence.*

## INTRODUCTION

Wide band gap GaN and related compounds with aluminium and indium currently have two main uses in commercial devices, providing bright LEDs emitting at ultraviolet-blue green wavelengths for CD-ROM and sensor applications and heterojunction field effect transistors (HFETs) which can sustain high current densities at elevated temperatures [1-2]. Further contributing to the outstanding performance of AlGaN/GaN based HFETs is the ability to achieve two dimensional electron gases (2DEGs) with sheet carrier concentration up to $10^{13}$ $cm^{-2}$ close to the interface, well in excess of those observed in other III-V material systems. This is because of a lattice mismatch between AlGaN and its GaN buffer layer. In a typical AlGaN/GaN heterostructure an AlGaN layer is grown on top of a thick GaN layer. Because the lattice constant of GaN is larger than that of AlN (by about %2.5), the AlGaN is grown pseudomorphically, with a biaxial tensile strain and a compressive strain along its hexagonal *c*-axis [3-4]. This strain produces a macroscopic piezoelectric polarization field in the AlGaN interface. The direction of the field depends on the polarity of the AlGaN growth surface. Recent studies have indicated that in typical AlGaN/GaN, which is grown by metalorganic vapor phase epitaxy (MOVPE), this surface (which is [0001]) has cation polarity so that the orientation of the field is in the same direction as the growth [5]. Today the most of LEDs and LDs use the nitrogen nano quantum structures in active region. The internal polarization fields effect on the optical characterizations. So the peak of photoluminescence spectrum and carrier recombination mechanism has also been affected. In these structures the aim is to screening the internal polarization fields using Si doping to increase the optical efficiency of optical devices.

## SAMPLES AND EXPERIMENTAL METHOD

Our quantum well samples of $GaN/Al_xGa_{1-x}N$ with Si in different sections are doped with uniform electron concentration of $6\times10^{18}$ $cm^{-3}$. Using The MOCVD method the quantum well structures are grown on the top of the aluminum oxide in (0001) direction. A buffer layer of AlN with thickness of 20 nm at low temperature and an middel layer of GaN with thickness of 2 $\mu m$ without impurity are also grown. Our structure are included of five quantum wells in each period. The thickness of the quantum wells and barriers for samples which are doped with Si are 31 and 76 angestrom, for just doping in well the thickness are 34 and 78 and for doping in the wells and barriers the thickness are 33 and 79 angestrom. The experiment has been done in temperature range of 2-300 K and for optical exitation wehave used a laser beam with wave length of 266 nm. The PL signal has been difracted by a single colour net and is detected by CCD detector that has been cold with liquid helium.

## RESULTS AND DISCUSSION

Figure 1 shows the photoluminescence spectrum of the three samples which are doped in different area at 2 K temperature. In both samples which are doped just the barrier and well and barrier, it can be seen that there is a shift to the higher energy in comparison to the bulk GaN (3.48 eV). The existence of internal fields in the samples cusses the Stark quantum effect that result in emission energy shifts to the lower energy. But due to the screening of internal energy by Si atoms the effect of Stark quantum effect is decreased and so emission energy shifted to higher energy level. On the other hand in the photoluminescence spectrum of the sample that is just doped in well there is high shift to the lower energy in comparison to the bulk GaN. We can not explain this shift in regard to the noting inherent carriers in well a little different in well width, because the well width in this sample is 34 angstrom which is lower than critical thickness. So the quantum confinement effect should cause an emission energy at higher energy of bulk GaN [6].

But in the experiment as it can be seen from figure 1 the emission energy from the sample that has doped quantum well the emission energy is so lower than bulk GaN. This is because of the existence of positive Si ions in the well. Because the Si ions cause a potential fluctuation in the well and therefore, causes the electron energy levels are shifted to the lower energy. In contrast, the holes energy levels on the other side of the well are shifted to the higher levels [7].

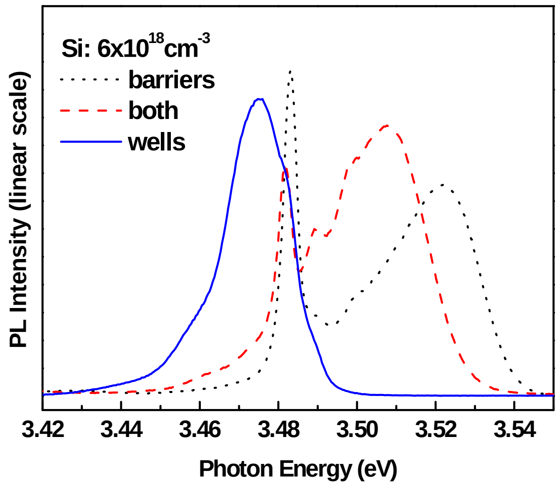


Fig. 1. The photoluminescence spectrum of the samples with different doping location at 2 K.

With studying of temperature dependence of photoluminescence's peak for the three samples it can be seen that in the first and in the second samples the recombination mechanisms are the same because the energy difference between photoluminescence's peaks in two samples from low temperature to room temperature is nearly the same (see figure 2). Whereas the peak of the energy different of the third sample in regard to the second sample is reduces from 33 meV at 2 K to 18 meV at room temperature. This shows a different recombination mechanism in this sample which is due to the Si ions in this well.

With increasing of the sample temperature from low temperature to room temperature due to the thermal excitation electrons are exited from the potential fluctuation in the well and this causes their difference energy of the recombination with the second sample is reduced to 18 meV at room temperature. In all the samples, especially in the third one which the well is doped the temperature dependence shows S behavior that is due to the recombination of the localized states. The localized energy state can be easily determined by comparison of peaks displacement.

## CONCLUSION

The optical properties of the three samples of GaN/$Al_xGa_{1-x}N$ multiple quantum wells which are doped with Si at different locations are studied. In the sample that has doped well there is an energy shift to the lower energy in comparison to the second sample. The shift of emission energy in the sample that has doped well is due to the electron-electron interaction. The positive ions in the well cause a potential fluctuation. This causes the electron motion in the present of the potential fluctuation shift the electron energy levels to the below and so the distance between the electron and hole energy levels are also decreased. Thus the red shift emission photoluminescence spectra are happened. Using the temperature dependence of the peaks from 2 K to the room temperature the kind of recombination mechanisms in the samples is known.

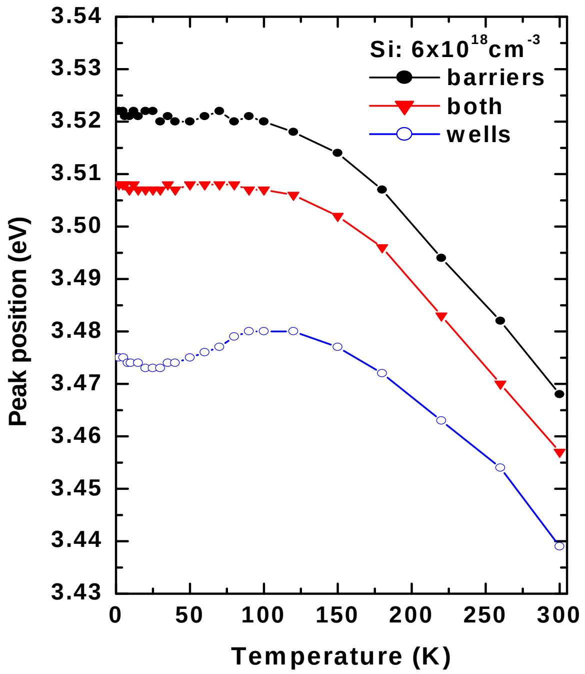


Fig. 2. The temperature dependence of the photoluminescence spectrum's peaks of three samples.

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