Interference effects on the photoluminescence of AlGaN/GaN quantum wells

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Group III-nitride semiconductor materials have enabled the design of nanostructures that can operate optically from the infrared to the ultraviolet of the electromagnetic spectrum, which are highly suitable for making electroluminescent devices, sensors and high efficiency solar cells [1].In this work we compared the propierties of AlGaN(50 nm)/GaN(5 nm) quantum wells (QWs) grown on Si(111), with those grown on sapphire substrates by Plasma Assisted Molecular Beam Epitaxy (PAMBE). The nanostructures were characterized structurally by high resolution X-ray diffraction (HRXRD) and scanning electron microscopy (SEM), which show the interfaces of the QWs, and the formation of wurtzite GaN and AlGaN. Optical properties were characterized by photoluminescence (PL), cathodoluminescence (CT) and reflectance (R) spectroscopies. Reflectance spectra show interference oscillations of the different layers, which disappear at the band gap edges of the GaN buffer layer (3.4 eV) and the AlGaN barrier layers (4.4 eV). The PL and CT spectra of the sample grown on sapphire show a strong emission (3 eV), which is consistent with recombination energy determined by self-consistent calculations taking in account a 4 MV/cm built-in electric field and low carrier densities. On the other hand, the sample grown on Si(111) presents a PL spectrum centered at 3 eV, which is modulated by the oscillations that match the reflectance spectrum (Figure 1). In order to understand the modulation of the photoluminescence spectrum, we measured PL and R spectra at different emission angles relative to the normal sample. The modulation peaks have a blue shift (Figure 2) when the angle θ_m at which the spectrum is measured increases because $Cos(\theta_m)$ decrease, and therefore the energy of constructive interference increase according to the interference condition (inset function). From these results we conclude that the photoluminescence modulation is due to the Fabry-Petrot interference of light emitted from the QWs when it is reflected at the GaN/Si(111) and AlGaN/air interfaces, which is not present in the sample grown on sapphire due to its wide band-bap.

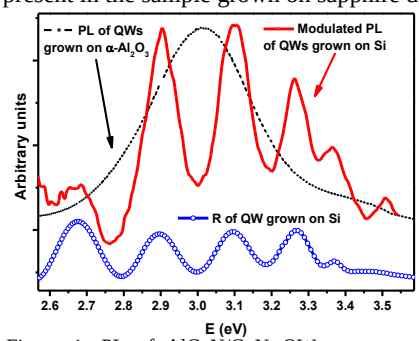

Figure 1. PL of AlGaN/GaN QWs grown on Si (continuous line) and Sapphire (dashed line). Reflectance of QWs grown on Si (open circles).

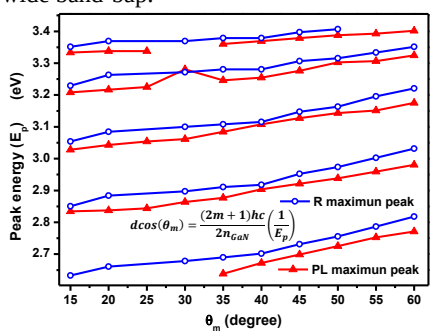

Figure 2. Angle dependence of PL (triangles) and reflectance (open circles) maximum ($\mathbf{E_p}$) for sample grown on Si.

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[1] Junqiao Wu, J. Appl. Phys. 106, 01110 (2009)