# OPTICAL EMISSION FROM SURFACE AND BURIED AlGaN/GaN MQWs GROWN BY MBE ON 6H-SiC

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In the recent literature many contributions have been concerned with the optical emission from AlGaN/GaN quantum wells (QWs), with the aim of developing the knowledge basis for their application to optical devices. Several effects have been identified, that affect the ground state emission energy in those particular MQW structures. The strain not only modifies the band structure via deformation potentials, but in these wurtzite heterostructures also a piezoelectric field must be taken into account. Furthermore, the lower symmetry of the wurtzite, as compared to the well known zincblende heterostructures, also induces internal polarization fields, known as spontaneous polarization. The discontinuities of the polarization at the heterojunctions induce high surface densities of polarization charges, which strongly bends the heterostructure band scheme in a saw-like profile.

In this contribution we want to point out a further effect, i.e. **the surface band bending**, which has been rarely discussed up to now in relation to the optical emission from nitride MQW structures. To this aim we have grown by MBE on 6H-SiC substrates two type of samples, referred in the following as surface and buried MQW. For both samples 10 periods of $Al_{0.25}Ga_{0.75}N$(4nm)/GaN(5nm) (MQW) were grown on a buffer structure consisting of AlN(25nm)/GaN(1$\mu$m)/AlGaN(25nm)/GaN(300nm), by starting from the SiC substrate. The surface and buried MQWs are the same structure grown on the buffer, with the only difference that a 100 nm thick GaN cap layer has been grown on the MQW in the buried sample. The AlGaN interlayer in the buffer, with an Al concentration varying between 10 and 25% has been introduced to improve the morphology of the sample surface, as seen by AFM.

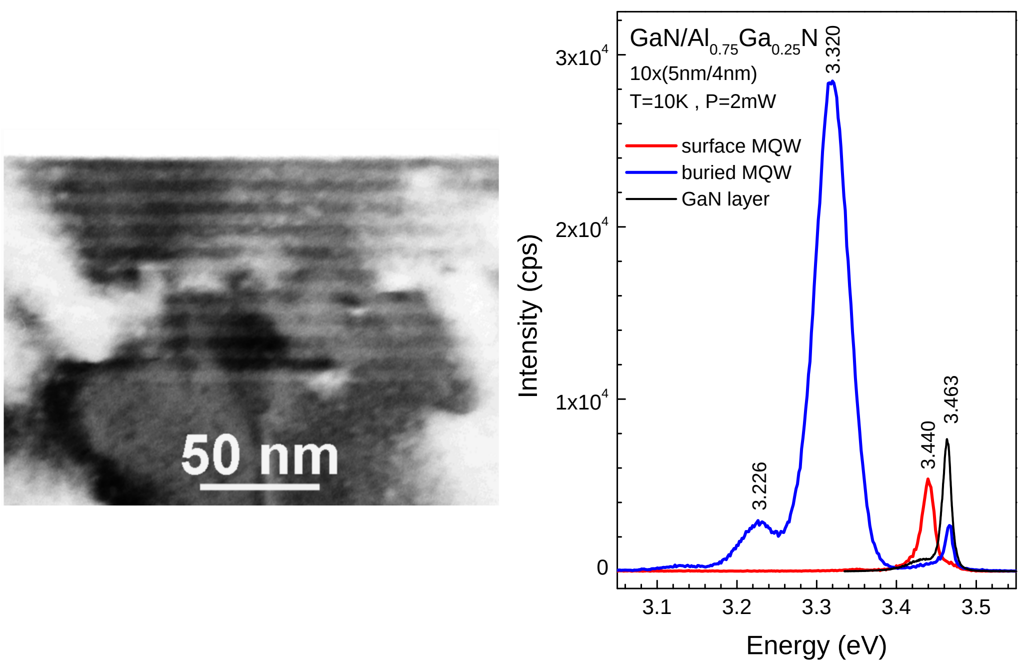


Figure 1: The left panel shows a TEM cross-section image of the AlGaN/GaN MWQ region in the surface MQW sample. PL spectra at 10 K of surface (red) and buried (blue) AlGaN/GaN MQWs are shown in the right panel. Also a spectrum of a 600 nm thick GaN grown on 6H-SiC is shown for comparison (black). The main peaks are labeled with their energy position, in eV.

The cross sectional TEM image in Fig. 1, showing a detail of the surface MQW region, reveals the very good structural quality of the MBE AlGaN/GaN MWQs. PL spectra measured at surface (red) and buried (blue) MQW samples at 10 K using the 325 nm line (3.815 eV) of a He-Cd laser are shown in Fig. 1, right panel. Also a representative PL spectrum of a MBE GaN layer grown on SiC (black) is plotted for comparison. The buried MQW sample presents a dominant feature at 3.320 eV, accompanied by phonon replicas in the lower energy side (94 meV energy distance for the first LO). The small emission at 3.466 eV overlaps very well with the main emission of a GaN MBE layer grown on SiC and it is therefore assigned to the emission from the GaN cap layer. The surface MQW sample shows a single sharp emission with a FWHM of 20 meV at 3.440 eV, clearly blue shifted with respect to the buried MQW.

The band diagram and the resulting quantized levels for the two heterostructures under study have been determined by solving iteratively the Poisson and Schrödinger equations in the effective mass approximation, with inclusion of the polarization fields in the model. The results are shown in Fig. 2, where the well known saw-like profile in the MQW region arises from the presence of polarization fields. Both structures end at the surface with a GaN layer and for both a surface level pinning of $E_C - E_F = 1$ eV has been considered, as measured by photoemission. A background n-doping of $6\times10^{16}$ cm$^{-3}$ is taken for the GaN MBE material.

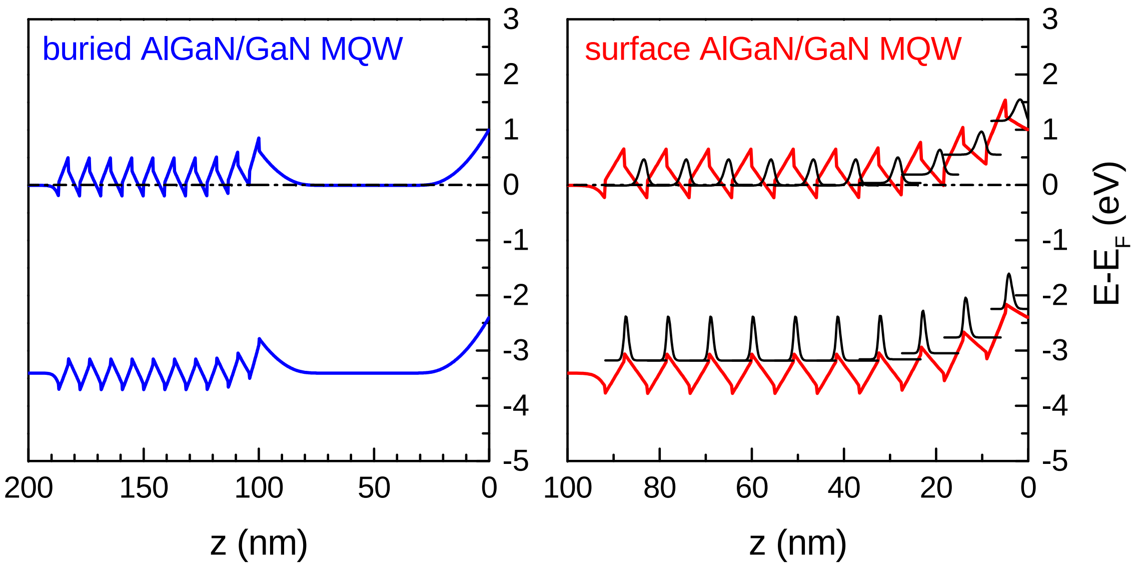


Figure 2: Self-consistently calculated conduction and valence band edges for the buried (left panel) and the surface (right panel) AlGaN/GaN MQW structures.

For the surface MQW structure (right panel), also the square of the absolute value of electron and hole wave functions is reported for each GaN QW (black). It can be seen, that the top most QW is strongly affected by *the Fermi level pinning, whose associated electric field reduces the polarization field in the first well.* The emission spectrum is expected to be a superposition of the emission from each QW. Actually, what we observe experimentally for the surface MQW is just a recombination blue shifted with respect to the emission from the deepest QWs, out of the band bending region. These latter would in fact give rise to the same emission energy as for the buried MQW sample. We assign the blue shifted emission to the top most QW, where the emission probability is higher than the underlying wells. The lowering of the quantum confined Stark effect (QCSE) by the surface band bending has as a consequence a higher overlap of the electron-hole wave functions in the top-most wells. Indeed, the optical matrix element for the first GaN QW is calculated to be 1-2 orders of magnitude higher than for the underlying ones. A contribution of screening effects leading to a quenching of the QCSE can be excluded, because of the low excitation power of 2mW in our experiments.

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