MBE Growth of Polar, Nonpolar and semipolar (Zn,Mg)O/ZnO for potential UV and THz applications

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ZnMgO/ZnO Quantum well heterostructures (QW) have attracted much attention due to their opportunity of combining band gap engineering, with large excitonic binding energies. So far, studies on ZnO have mainly focused on films grown on c-(0001) plane. Unfortunately, the wurtzite ZnO layers exhibit built-in electric fields along the c-axis, affecting the electronic properties. In this presentation, we will demonstrate that the non-polar surfaces are an alternative route for the fabrication of wide QWs with no reduction of the exciton binding energies. This property is first demonstrated in QWs grown on sapphire. Then we show a drastic improvement of the structural properties when the QWs are grown on ZnO substrates: no residual strain, smooth interfaces, no extended defects, reduced surface roughness, reduced X-Ray full width at half maximum. A strong enhancement of the photoluminescence (PL) properties is also demonstrated compared to heteroepitaxial QWs and the integrated PL intensity can be constant as a function of the temperature up to RT after optimization. Light emitting devices were then fabricated with these active layers. The structural quality does not deteriorate even after the growth of the n-type and nitrogen doped ZnMgO layers as "p-type" layer. The devices exhibit a clear rectifying behavior. Under forward bias a clear emission from the 4nm QWs is observed at 373nm, close to the QW PL (371nm). However the outpower is still very poor due to the lack of efficient p-type doping.

In order to avoid the limitation of the p-type doping, we propose and demonstrate the potential of the nonpolar ZnO/(Zn,Mg)O material system as a candidate for intersubband (ISB) devices, which do not require p-type layers. This material system presents a unique set of properties that makes it highly attractive for mid-IR and THz emission as well as for strong coupling regimes: (1) it can be doped up to 10^{21} cm^{-3}, (2) it has a very large longitudinal phonon energy of 72 meV, (3) it is very ionic with a large difference between the static and high frequency dielectric constants. After optimization, the QW interface roughness is in the range of a few Å without defect or strong composition fluctuations. The doping level is then optimized to reach n~$5x10^{20}$ cm^{-3} in ZnO (n above $5x10^{13}$ cm^{-2} in our QWs). Thanks to the careful optimization of the growth conditions, ISBT are observe for the first time in nonpolar ZnO-based heterostructures

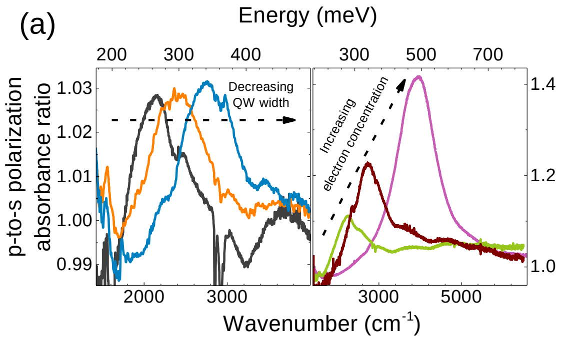

Fig. 1: p to s polarization absorbance ratio for the MQW structures presented here for (a) different QW widths (b) different -type doping.

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