In(Ga)N/GaN short period superlattices

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Short-period *m*InN/*n*GaN (*m*InGaN/*n*InGaN) superlattices (SPSL) consist of small number of monolayers (MLs) *m* and *n*. They are new group of nitride semiconductor structures which allow band gap engineering in violet-blue-green range of the spectrum. By these means the difficulties in obtaining high-quality InGaN quantum wells with large In-content may be avoided. Precise control of energy gap in wide spectral range opens up new possibilities for the future application. Furthermore, the use of an ultrathin InN QW can enhance the emission intensity through the increased spatial overlap of electron and hole wavefunctions. There are also other potential aspects of using of nitride superlattices like e.g. topological insulators, superlattice-doping by Mg-acceptors, or strain compensation by using subsequent layers with special choice of lattice constants.

Several leading laboratories attempted to obtain superlattices with small number of InN atomic layers. Reported so far experimental results, show very similar photoluminescence energy values (3.2-3.35 eV). Large discrepancy occurred when comparing the measured E_{PL} values to the ab-initio calculations (based on the Local Density Approximation to density functional theory) of E_g values for 1InN/*n*GaN SLs. From theoretical calculations band gap energy for 1InN/*n*GaN SPSL should be around 2 eV. Similar discrepancy between theory and experiment were found in case of high pressure measurements. It is important to point out that in these SPSL the huge electric field (up to 10 MV/cm) were found by the theoretical calculations.

Some hypotheses were proposed to explain this discrepancy: i) optical transitions are attributed to GaN excitons partially localized in the InN region, ii) screening of the internal electric fields in the polar structures by free carriers originating from unintentional defects. Results from different research groups were not conclusive, until new hypothesis appeared, which assumes that instead of pure InN monolayer in fact monolayer of InGaN is formed. This hypothesis was confirmed by our theoretical and experimental results. It turned out that InGaN layer contains 33% of In.

Obtained results suggest that there can be general problem in obtaining pure monolayers of InN embedded in GaN matrix, since large differences in the bond lengths between InN and GaN might lead to the mechanism of In-incorporation reduction. According to theoretical prediction of Duff et al. [1], problem of strain generated during growth can be solved by applying substrates or pseudosubstrates with InGaN thick layer what in case of pseudomorphic growth conditions induces lower strain in entire SPSL structure. To check this prediction, set of samples with InGaN/GaN SPSL on relaxed InGaN layers (with various thickness), were grown at Unipress.

The performed XRD measurements confirmed decrease of strain in our samples with InGaN pseudosubstrates. Better lattice matching caused reduction of photoluminescence energy down to 2.95 eV. We will discuss the shift of PL energy in the samples grown on pseudosubstrates in terms of In content in InGaN quantum well and lowering built in strain.

[1]. A. I. Duff, L. Lymperakis, J. Neugebauer, Phys. Rev. B 89, 085307 (2014).