InN/GaN Short Period Superlattices grown by Plasma Assisted MBE

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Ultra thin InN/GaN short-period superlattices (SPSL) consisting of single or few atomic monolayers (ML) of InN and GaN are interesting for growth of high In content digital alloys. They may become an alternative for InGaN/GaN quantum structure used for light emitting diodes (LEDs) and laser diodes (LDs) in a vast spectral range where large lattice mismatch between InN and GaN makes the growth of high In content InGaN layers very challenging. InN/GaN SPSL grown by Plasma Assisted Molecular Beam Epitaxy (PAMBE) permits gap engineering in the blue-green range of the light spectrum. Also it can be useful for effective manipulation of the internal polarization fields in InGaN QWs, high efficiency multi-junction solar cell applications and topological insulators [1]. Yoshikava et al. [2] claimed to achieve growth of such SPSL with 1 ML of InN at high temperatures (e.g. 650°C) at which thicker InN layers are decomposing. However, intriguing work was done recently by Suski et al. [3], where careful TEM studies of InN/GaN SPSL grown at such conditions showed that SPSL contain not 1 ML of InN, but 1 ML of InGaN with 33% of In. Also Duff et al. [4] suggests that for pseudomorphic growth on GaN substrates, thin InN layer is intrinsically unstable due to lower In and Ga chemical potentials. They have theoretically predicted a window for growth of InN which appears for substrates of higher lattice parameters. An $In_{0.25}Ga_{0.75}N$ substrate would meet these criteria.

In this work we investigate InN/GaN short period superlattices (SPSL) grown by PAMBE at temperature range 650°C - 580°C on two types of substrates. Directly on (0001) MOVPE GaN/sapphire and special substrates having relaxed $In_{0.2}Ga_{0.8}N$ buffers on top of (0001) GaN/sapphire where the lattice constant "a" is higher than for GaN. The properties of InN/GaN SPSL grown on such substrates are compared using low temperature PL and XRD method. For the SPSL grown coherently to GaN substrate XRD and HRTEM analysis show that instead of 1 ML of InN we have 1 ML of InGaN with In content of 11-22%. On the other hand for the growth of SPSL on relaxed InGaN buffers it was possible to achieve 1 ML of pure InN as it is confirmed by XRD data. Moreover, we observed a strong photoluminescence shift to longer wavelengths for SPSL grown on substrates with higher relaxation which supports the XRD results. We discuss the impact of substrate a-lattice constant and growth temperature for growth of 1 ML containing more than 30% of In and identify the mechanisms which allows to achieve 1ML of InN. We compare experimental results with theoretical simulations of SPSL variation with the well and the barrier thicknesses using band structure calculation in the Local Density Approximation with a semiempirical correction for the gap error.

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