Infrared ellipsometry study of strained hexagonal AlN/GaN superlattices

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AlN/GaN and AlGaN/GaN superlattices (SLs) have been subject of intense investigation due to their potential applications for high power transistors and ultraviolet laser diodes. However, only a few reports are devoted to their vibrational properties. Experimental and theoretical studies of phonons in AlN/GaN SLs have revealed the presence of quasi-confined and interface modes at frequencies different from those of bulk AlN and GaN [1,2]. The formation of SL also induces a folding of the Brillouin zone in the growth direction, which is expected to provoke the appearance of new phonon modes. In addition, the SL constituents are under strain resulting in strain-induced shift of the SL phonon frequencies, which further complicates the mode identification.

In this work we report on comprehensive study of the vibrational properties of strained AlN/GaN SLs. The SLs were grown by metalorganic vapor phase epitaxy on (0001) sapphire substrates using GaN buffer layer. The structures consist of 10 period SLs with different well thicknesses, keeping the well-barrier thickness ratio as 3:1. The SLs were studied by infrared spectroscopic ellipsometry (IRSE) and high resolution reciprocal space mapping (RSM).

The 10-14 RSM of the short-period SL shows that the SL is grown coherently on the GaN layer and both the barrier and the well have the same in-plane lattice parameter as the underlying GaN layer. In other words there is a large tensile strain in the AlN layers and a small compressive strain in the GaN wells. The latter is manifested by a small shift of 2 cm^{-1} of the GaN E_1(TO) frequency from the strain-free position. We found that with increasing the SL period the AlN barrier layers start to relax, which is reflected by the increase of the AlN E_1(TO) frequency towards the strain-free value. Accordingly, the compressive strain in the GaN well layers increases as evidenced by the blue-shift of the GaN E_1(TO) mode. The observed GaN and AlN E_1(TO) modes are suggested to be confined modes within the SL constituents. A_1(LO) mode belonging to the SL AlN sublayers was also detected and it shifts to higher frequencies with increasing the barrier thickness reflecting the strain decrease in the sublayers. The E_1(LO) mode of the AlN sublayers is identified at frequencies lower than the strain-free value of AlN and higher than the strain-free value of GaN showing a behaviour of “normal” delocalised mode [3]. In addition, two other modes belonging to the SL structure are identified in the IRSE spectra of all samples and are suggested to be interface excitations or originating from the Brillouin zone folding.

References

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