NONRADIATIVE PROCESSES AND PHONON EMISSION IN GaAsN ALLOYS

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The compound semiconductor GaN and its alloys are of great interest because of their applications in blue/UV optoelectronic devices. Recently we have demonstrated strong blue light emission at room temperature in As-doped GaN thin films [1]. Although the quantum efficiency is higher than in bulk GaN, it is still low and more than 90% of the carriers initial energy is lost non-radiatively through phonon emission. Therefore, to optimize material parameters for device applications it is important to understand the processes of carrier relaxation and non-radiative recombination. This is the aim of the present work, in which we make direct measurements of the phonons emitted by optically excited GaAsN and correlate them with photoluminescence (PL) measurements.

The samples were undoped and As-doped GaN films were grown by plasma assisted molecular beam epitaxy on sapphire substrates at 800°C. Active nitrogen was provided by an RF plasma source. The samples were excited by 10 ns pulses from a 355nm laser focussed to a spot 50 μm in diameter. Peak power densities of up to 10^4 W/cm^2 were used. The emitted phonons were detected with nanosecond time resolution at T=2K using superconducting aluminium bolometers evaporated onto the back side of the sapphire substrate. We scanned the position of the excitation spot relative to the bolometer using a computer-controlled system of mirrors in order to obtain an image of the phonon intensity as a function of the propagation direction. We also measured the blue (2.6eV) PL decay in the As-doped GaN samples using a fast photodiode under the same excitation conditions.

We have measured the time evolution of the phonon emission signals in the undoped GaN and the As-doped GaN samples. In the undoped sample the mean duration of the phonon emission pulse has a value ~100 ns, which is mainly governed by the phonon scattering processes in sapphire substrate. However, in the As-doped GaN samples the duration of the phonon pulse is ~50 ns longer than in the undoped GaN layers. This difference between the two samples indicates that in the As-doped GaN there are slow non-radiative processes, which include carrier energy relaxation and non-radiative recombination.

It is interesting to note that the decay time of phonon emission pulse has a value similar to the decay time of the blue PL. The fact that both phonon and PL emissions show similar decay behavior leads us to conclusion that the PL decay time of ~100 ns in the sample with As is probably connected with a nonradiative process rather than with radiative recombination. We discuss several nonradiative relaxation and recombination processes, which may be responsible for slow phonon and PL emissions in As-doped GaN films: donor-acceptor recombination; phonon bottleneck and energy relaxation via localised tail states.

[1] C. T. Foxon, S. V. Novikov, T. S. Cheng, C. S. Davis, R. P. Campion, A. J. Winser and I. Harrison, J. Crystal Growth **219**, 327 (2000).