Molecular-beam epitaxy growth and characterization of cubic $Ga_{1-x}In_xN$ across the entire composition range

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The zincblende phase of group III-nitrides, i.e., their cubic form, shows promise for next-generation optoelectronic devices. The cubic phases unlike their thermodynamically stable wurtzite counterparts do not feature any internal piezoelectric fields due to structural symmetry. This is a significant advantage for the realization of robust, i.e., wavelength stable emitters due to the absence of any significant intrinsic quantum-confined Stark effect.

Of particular interest is cubic $Ga_{1-x}In_xN$. Tuning of its composition and, thereby, directly its bandgap energy and optical emission energy covers the electromagnetic spectrum from ultraviolet to infrared. However, the heteroepitaxial growth of metastable $Ga_{1-x}In_xN$ poses numerous challenges, including the lack of appropriate substrates, a narrow growth window, and significant differences in lattice constants between the two binary compounds. Consequently, there are few reports of $Ga_{1-x}In_xN$ with x(In) > 0.3, with some publications even indicating spinodal decomposition for intermediate indium contents [1, 2].

This perceived miscibility gap of c-GaN and c-InN is readily overcome using molecular beam epitaxy (MBE) growth of c-$Ga_{1-x}In_xN$ layers [3] on smooth c-GaN/AlN/3C-SiC/Si templates [4]. Post-growth, the composition, phase purity, and strain relaxation of the thin films become evident in reciprocal space maps. They clearly reveal a relationship between the amount of indium content and strain which strongly influences the alloys' miscibility. All samples show emission covering the expected spectral range. Notably, we find only minor efficiency droops of about a factor of two across the Si detection range (< 1.2 eV). The photoluminescence data confirms the postulated tunability of the emission energy from 0.7 to 3.24 eV.

Scanning transmission electron microscopy infers a copper-platinum-type ordering for intermediate indium contents which is supported by more narrow-band spectral emission for these compositions. This work poses a significant advance towards the realization of emitters across the broad wavelength window using the arsenic-free cubic nitrides only.

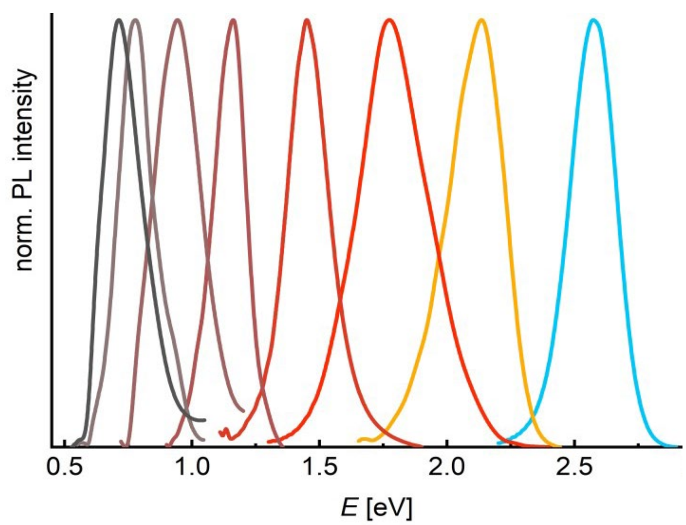

Fig.1. Normalized low-temperature (T = approx. 20 K) photoluminescence spectra of c-$Ga_{1-x}In_xN$ over the whole composition range (x = 1.0, 0.92, 0.72, 0.59, 0.47, 0.36, 0.27, 0.11 from left to right).

References

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