Limits for indium incorporation to InAlN grown by plasma-assisted MBE

Natalia Fiuczek [1,2], **Paweł Wolny** [1], **Anna Feduniewicz-Żmuda**[1], **Marcin Kryśko** [1], **K. Nowakowski-Szkudlarek** [1], **Marcin Siekacz** [1], **Grzegorz Muzioł** [1], **Henryk Turski** [1], **Julita Smalc-Koziorowska**[1,2], **Žarko Gačević** [3], **Enrique Calleja**[3], **Czesław Skierbiszewski** [1,4] **and Marta Sawicka** [1]

[1] *Institute of High Pressure Physics PAS, Sokołowska 29/37, 01-142 Warsaw, Poland*
[2] *Faculty of Applied Physics and Mathematics, Gdańsk Univeristy of Technology ul. Narutowicza 11/12, 80-233 Gdańsk, Poland*
[3] *ISOM-ETSIT Universidad Politécnica de Madrid, Spain*
[4] *TopGaN Sp. z o.o., Sokołowska 29/37, 01-142 Warsaw, Poland*

$In_{0.17}Al_{0.83}N$ lattice-matched to GaN has ~7.3% refractive index contrast to GaN and therefore it can be used for the fabrication of distributed Bragg reflectors (DBRs) that are building blocks of nitride vertical surface cavity emitting lasers (VCSELs). However, the growth of high quality InAlN poses a challenge due to large bond strength differences between InN and AlN. The indium content in InAlN strongly decreases with increasing growth temperature due to severe In-N bonds decomposition. Therefore the growth window for $In_{0.17}Al_{0.83}N$ grown on (0001) GaN by plasma-assisted molecular beam epitaxy (PAMBE) is limited to temperatures as low as 500-560°C [1, 2] while the growth of InGaN or AlGaN is typically carried out at 650 and 730°C, respectively.

It is believed that low growth temperature hinders Al adatoms diffusion on the surface and promotes composition inhomogeneity formation in InAlN layers [3]. Figure 1(a) presents the typical fingerprint of uneven In incorporation, i.e. a "honeycomb" microstructure reported for the $In_{0.17}Al_{0.83}N$ layers grown with low N-flux at relatively low temperature. The In-rich regions appear with brighter contrast.

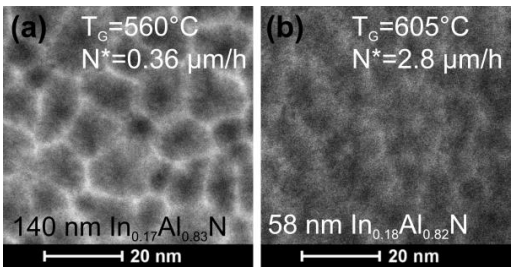

Figure 1. Plan-view scanning transmission electron microscope images of InAlN layers grown by PAMBE. The In-rich regions appear with brighter contrast and are visible in both layers.

In this work we use high active nitrogen flux N* for the In-N bond stabilization. $In_{0.17}Al_{0.83}N$ layers were grown with N* = 2.8 µm/h at 605°C that is the highest temperature for lattice-matched InAlN reported so far by PAMBE on (0001) GaN. In Figure 1(b) we show that despite the significant increase in growth temperature the composition inhomogeneity was not completely eliminated. Further increase of the growth temperature while keeping the In content ~17% would require even larger active N* fluxes that are challenging to obtain in PAMBE. We will discuss these limitations. Last but not least we will report on the optical properties of InAlN/GaN DBR structures and compare to DBRs previously grown by PAMBE [4].

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