# High-reflectivity $Al_xGa_{1-x}N$ Bragg Reflectors in the Ultraviolet Spectral Region

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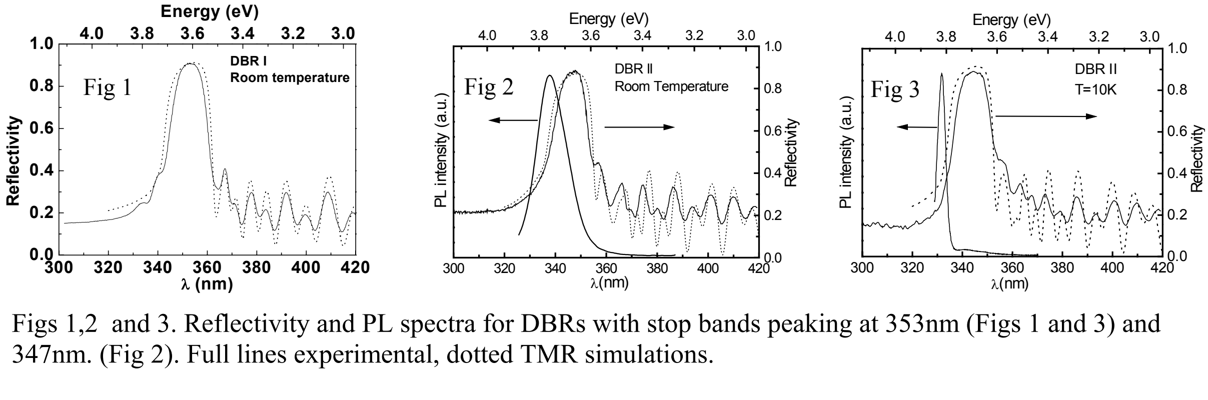
High reflectivity distributed Bragg reflectors (DBRs) are an essential pre-requisite for the fabrication of high Q-factor cavities, which in turn are necessary to achieve strong exciton-photon coupling. As well as the application in polariton physics, high reflectivity DBRs in GaN systems also have important application in the fabrication of high efficiency LEDs and potentially VCSELs. In order to achieve strong coupling in GaN-based systems, as well as high cavity Qs (in excess of ~200, corresponding to DBR reflectivities greater than ~90%), relatively narrow linewidth (~20-40meV) QWs are also required. The need for 'narrow' exciton lines implies that the QWs must have either low or zero In-content, with consequent wavelength of ~350nm in the ultraviolet (uv) spectral region. The consequent requirement for uv DBRs poses special challenges which do not arise at longer wavelength (e.g. in the blue at 400nm). These challenges are however not insurmountable, as we describe below.

We report the growth of crack-free AlGaN DBRs with reflectivity in the uv as high as 94% from 25 layer repeats. The DBRs are grown by MOCVD on sapphire substrates. Following growth of a GaN buffer layer, an AlN interlayer was grown to prevent crack formation. 25 layer repeat $Al_xGa_{1-x}N$-$Al_yGa_{1-y}N$ DBRs were then grown for a range of x, y values, with focus on x=0.16, y=0.49. The x=0.16 band gap is ~335nm, the composition chosen such that the DBR band gaps are at shorter wavelength than likely DBR stop band maxima. The 300K reflectivity spectrum for a structure (DBR1) designed for peak reflectivity of 353nm is shown in Fig 1. It exhibits reflectivity of 91%, and stop band width of 17nm. The spectrum is reproduced well by transfer matrix (TMR) simulations including real and imaginary parts of the dielectric functions of the full structure (see Fig 1).

Spectra for DBRII, very similar to DBR1 but with peak wavelength of 347nm, are shown in Fig 2. In this case lower reflectivity of 87% and an asymmetric stop band are found, with rapid fall off on the high energy side. The origin of the lower reflectivity is revealed by the low temperature (T) studies in Fig 3: the reflectivity increases to over 90%, and a symmetric stop band is now found, very similar to that for the 353nm DBR in Fig 1. We attribute the asymmetric shape in Fig 2 to band tail absorption from the AlGaN (x=0.16) layers, whose effect is markedly reduced at low temperature by the ~80meV increase in band gap. This interpretation is strongly supported by the TMR simulations in Figs 2 and 3, performed for the same set of input parameters, but using the layer band gaps at 300 and 10K (the PL spectra in Figs 2 and 3 provide a direct measure of the change of the $Al_{0.16}Ga_{0.84}N$ band gap with T).

The main message of this work is thus that it is essential to minimize absorption, even when operating below nominal AlGaN band gaps, to obtain high reflectivity GaN-based DBRs. This result is further confirmed by recent results we have obtained on x=0.2, y=0.6 DBRs, where reflectivity as high as 94% is obtained, a result of the further shift of band gap to higher energy. We note finally that it is also necessary to minimize absorption in the cavity regions to obtain high Q GaN cavities.




Figs 1,2 and 3. Reflectivity and PL spectra for DBRs with stop bands peaking at 353nm (Figs 1 and 3) and 347nm. (Fig 2). Full lines experimental, dotted TMR simulations.