Enhancement of Intersubband Absorption in GaInN/AlInN Quantum Wells

G. Cywiński [1], C. Skierbiszewski [1], A. Feduniewicz-Żmuda [2], M. Kryśko [1], R. Kudrawiec [3], M. Gladysiewicz [3], J. Misiewicz [3], L. Nevou [4], N. Kheirodin [4] and F. H. Julien [4]

[1] *Institute of High Pressure Physics, Polish Academy of Sciences, 01-142 Warsaw, Poland*
[2] *TopGaN Ltd, 01-142 Warsaw, Poland*
[3] *Institute of Physics, Wrocław University of Technology, 50-370 Wrocław, Poland*
[4] *Institut d'Electronique Fondamentale, Université Paris-Sud, UMR 8622 CNRS, 91405 Orsay, France*

Recently, there has been increasing interest in III-nitride semiconductors for the fabrication of ultrahigh-speed intersubband (ISB) devices. First of all it is due to the large conduction band discontinuity available in these materials. The very deep quantum wells (QW) which can be fabricated, are used as an active region for ISB devices for telecommunication applications (1.55 and 1.3 μm). Moreover the ISB absorption recovery times in nitride semiconductors are extremely short, typically of the order of 150-400 fs due to enhanced electron-phonon interaction in these highly ionic materials [1]. One can expect that ISB devices could provide ultrafast data transfer in a single channel of optical fiber. The predicted speed should be in the range of 0.1-1 Tbit/s bit-rate regime, which is significantly larger than the speed achieved with current bipolar technology.

Our work has focused on the growth of GaInN/AlInN multi QWs on GaN substrates. Properly choosing growth parameters we were able to fabricate high quality ISB structures exhibiting intense ISB absorptions at 1.55 μm [2]. Due to a partially strain compensation even quite thick structures were crack free. However, an application of such structures in high-speed ISB devices requires extremely good optical and electrical parameters, which should be appropriate for μ-size devices. In the present work we show a significant enhancement of ISB absorption for 15.5 Å thick GaInN QWs due to increase of the AlInN barrier width. The enhancement of ISB absorption was more then 3 times for enlarged barrier width from 3 to 6 nm. Also, we observe that the barrier width does not influence the energy of interband and intersubband transitions within experimental accuracy. The experimental results have been compared with theoretical calculations which were performed within the electron effective mass approximation solving the Schrödinger and Poisson equations self-consistently. Strain effects as well as the effect of spontaneous and piezoelectric polarization have been included in these calculations. A good agreement between experimental data and theoretical calculations has been observed for the investigated samples. By analyzing the electron wave functions, it has been concluded that the electrons significantly penetrate the quantum well barriers and that the QWs are coupled despite the fact that the energy coupling between QW levels is very weak. The observed enhancement of ISB transitions can be associated with the effect of better localization of the second electron level in QW. This finding seems to be very important and useful to optimize ISB devices. In this paper this issue will be discussed in details.

This work was partially supported by the Polish Ministry of Science and Higher Education as scientific projects Nos. N507 011 32/0500 and N202 41090 33.

[1] N. Iizuka, K. Kaneko, N. Suzuki, T. Asano, S. Noda, and O. Wada, *Appl. Phys. Lett.* **77**, 648 (2000).
[2] G. Cywiński, C. Skierbiszewski, A. Feduniewicz-Żmuda, M. Siekacz, L. Nevou, et al., *Vac. Sci. Technol. B* **24**, 1505 (2006).