EELS-HAADF combination for characterization of a new AlN/GaN DBRs growth method.

A. Eljarrat[1], L. López-Conesa[1], Ž. Gačević[2], S. Fernández-Garrido[2, 3], E. Calleja[2], C. Magén[4, 5], S. Estradé[1, 6] and F. Peiró[1]

1. Lab. of Electron NanoScopies, LENS-MIND-IN2UB, Dept. Electrònica, Univ. de Barcelona, Spain.
2. Instituto de Sistemas Optoelectrónicos y Microtecnología, ISOM, Univ. Politécnica de Madrid, Spain.
3. Also at Paul-Drude-Institute for Solid State Electronics, Hausvogteiplatz 5-10117 Berlin, Germany.
4. Laboratorio de Microscopías Avanzadas (LMA) - Instituto de Nanociencia de Aragón (INA) and Departamento de Física de la Materia Condensada, Universidad de Zaragoza, 50018 Zaragoza, Spain.
5. Fundación ARAID, 50004 Zaragoza, Spain.
6. TEM-MAT, (CCiT), Universitat de Barcelona, Solís i Sabarís 1, Barcelona, Spain

Email: aeljarrat@el.ub.edu
Keywords: group III nitrides, HAADF, EELS, STEM

Group III nitride materials promise production of optoelectronic devices that cover the entire visible range thanks to their widely–tunable room–temperature band gap energy. Nevertheless, in–plane lattice mismatch between the binary components is an issue affecting their design and growth. This causes proneness of the structures to present defects at the interfaces between compounds, finally decreasing the overall performance of the devices. In the present case we deal with a heterostructure of the binaries AlN/GaN for the configuration of distributed Bragg reflectors (DBR) [1-3].

This work proposes a new method for the growth of high reflectivity, crack–free, AlN/GaN DBRs. This new method has been tested by growing 6, 10 and 20 period samples that are presented and characterized through various techniques. Reflectivity and X-ray diffraction reciprocal space mapping (XRD–RSM) measurements have been performed. These methods are useful for testing optical and structural properties of the samples, viewed as a whole. Moreover, the sample is thoroughly probed at a local scale through combined high angle annular dark field (HAADF) and low-loss electron energy loss spectroscopy (EELS) in a scanning transmission electron microscope (STEM) equipped with an aberration corrected and a monochromator. Our own-made computer routines are presented as they are useful in the automatization of the analysis of this kind of spectra [4-5]. The combination of these techniques and the great quality of the measured data allows us to recover information of the sample at the nanoscale, with sub-eV energy resolution (for the EEL spectra [6]). Besides the complete structural characterization of the AlN and GaN layers, the formation of AlGaN transient layers is demonstrated (thick and thin, see Fig.1). The origin of these layers is investigated and its impact in the DBRs optical properties is discussed.

Z contrasts imaging shows that structural quality is preserved through the formation of transient AlGaN layers with exceptionally high reproducibility of the segregation phenomenon (See Fig. 1). Peak reflectivity and stopband width results are presented for all the samples and compared to theoretically expected values. The analysis points out that to further improve the optical performance of the DBRs, the thicker transient AlGaN interlayer has to be significantly reduced. This would increase interface abruptness and decrease the “thickness disorder” bringing thus direct benefits to the peak reflectivity and stopband width. The mechanisms to control interlayer thickness remain unclear at the moment, constraining thus further advance. Reflectivity in our samples is high (> 90%), and XRD-RSM has shown a good structural quality, assessed by HAADF-STEM micrographs showing a crack–free, highly periodic structure, up to 20 periods. These properties suggest the possibility of growing an active layer on top of the DBR. The widths of four layers that compose the periodic heterostructure are measured through the combined HAADF-EELS techniques: ~ 10, 15, 50 and 15 nm for AlGaN1 (AlN–on–GaN), GaN, AlGaN2 (GaN–on–AlN) and AlN layers.

The combination of EELS and HAADF in STEM has proved to be a valuable tool in the characterization of structural properties from local measurements with great spatial resolution and chemical sensibility.

References

[1] T. Ive, O. Brandt, H. Kostial, T. Hesjedal, M. Ramsteiner, and K. H. Ploog, Appl. Phys. Lett. **85** (2004).
[2] G. Koblmueller, F. Wu, T. Mates, J. Speck, S. Fernandez-Garrido, and E. Calleja, Appl. Phys. Lett. **91** (2007).
[3] G. Koblmueller, R. Averbeck, L. Geelhaar, H. Riechert, W. Hosler, and P. Pongratz, J. Appl. Phys. **93** (2003).
[4] A. Eljarrat, Z. Gacevic, S. Fernández-Garrido, E. Calleja, C. Magén, S. Estradé, and F. Peiró, Journal of Physics: Conference Series **326** (2011).
[5] Z. Gacevic, S. Fernández-Garrido, D. Hosseini, S. Estradé, F. Peiró, and E. Calleja, J. Appl. Phys. **108**, 113117 (2010).
[6] R. F. Egerton, Rep. Mod. Phys. **72**, 016502 (2009).

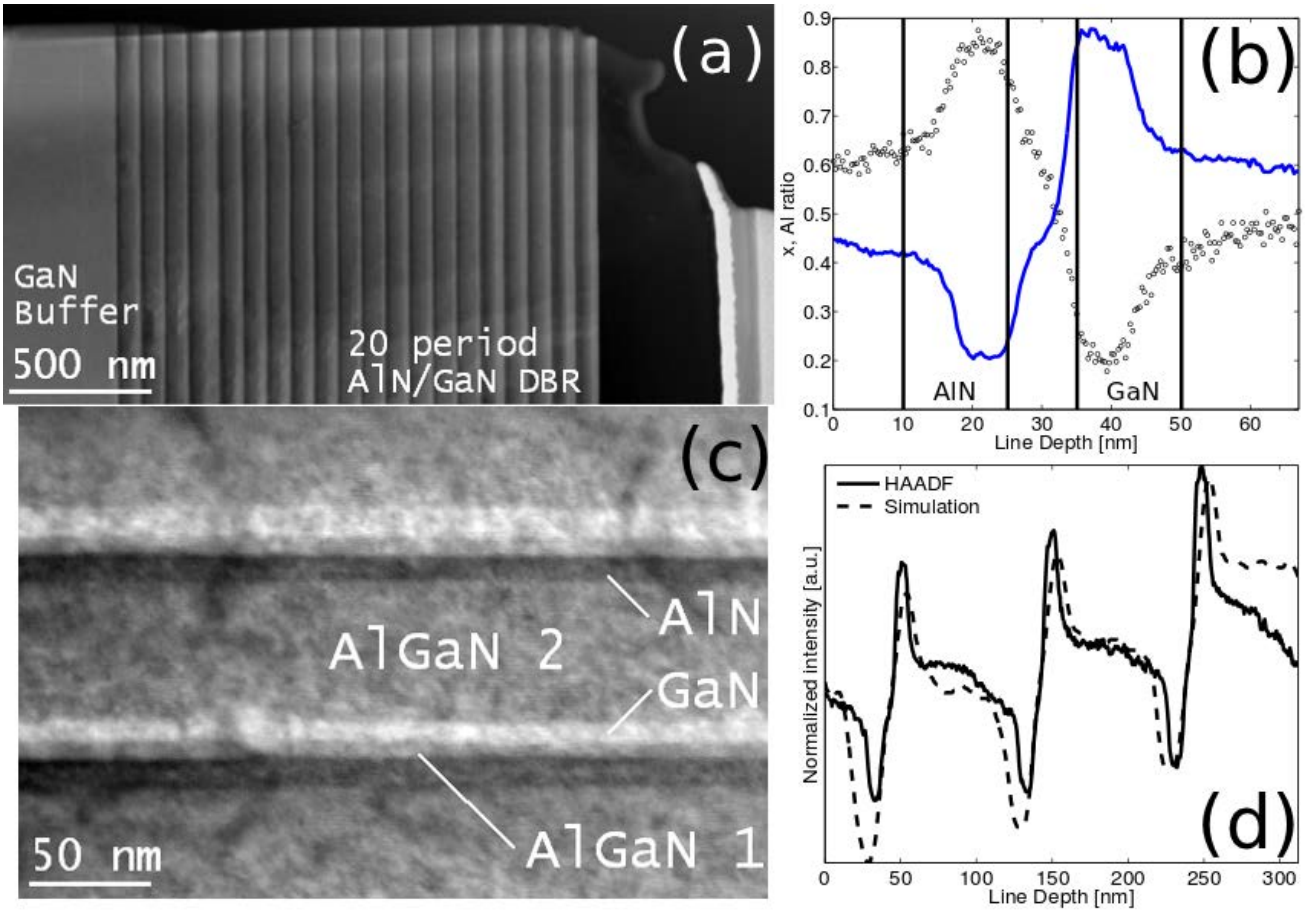

Figure 1. *(a) STEM-HAADF image of a 20-period AlN/GaN DBR showing the full structure, from the GaN buried layer at right hand side to the top of the DBR. The high periodicity of the structure is appreciated in this image, while lower panel (c) shows a detail of two successive periods. Top graph, (b), shows the aluminum ratio profiles (circles) calculated through Vegard Law analysis of the plasmon excitation energy position along with the HAADF intensity profile (blue). Below, (d), both experimental and simulated HAADF intensity profiles, along 3 periods are shown. Interfaces between each one of the layers composing the structure can be identified separately in these plots, for this purpose, AlN and GaN layer limits are included in (b).*