P-07

PHOTOEMISSION STUDIES OF $Ga_{0.92}In_{0.08}N(0001)$ AND GaN(0001)

B.J. Kowalski[1], I.A. Kowalik[1], R.J. Iwanowski[1], B.A. Orlowski[1], E. Łusakowska[1], J. Sadowski[1,2], J. Kanski[3], J. Ghijsen[4], F. Mirabella[4], P. Perlin[5], S. Porowski[5], I. Grzegory[5], and M. Leszczynski[5]

[1]Institute of Physics, Polish Academy of Sciences, PL-02-668 Warszawa, Poland
[2]MAX Laboratory, Lund University, SE-221 00 Lund, Sweden[3]Chalmers University of Technology and Göteborg University, SE-412 96 Göteborg, Sweden
[4]Facultés Universitaires Notre-Dame de la Paix, LISE, B-5000 Namur, Belgium
[5]High Pressure Research Center, Polish Academy of Sciences, PL-01-141 Warszawa, Poland

Nitrides attract considerable interest mainly due to their application for fabrication of LEDs and laser diodes used in the UV, blue and green spectral regions [1]. Indium in the GaN matrix causes a narrowing of the energy gap of the material from 3.5 to 1.9 eV and makes it possible to tune the energy of light emitted by the device. Promising applications as well as interesting physical phenomena governing the radiative recombination of carriers have stimulated intensive investigations of this material. In particular, detailed information about the electronic structure is important for both applications and research of elementary excitations in it. However, experimental evidence concerning band structure of $Ga_{1-x}In_xN$ is scarce, except of that obtained mainly by various optical measurements and referred to the edges of the bands forming the fundamental energy gap. The density of states in the whole valence and conduction bands was investigated by soft X-ray emission and absorption [2]. Photoelectron spectroscopy is widely accepted as one of the most suitable tools for studies of electronic states. In particular, use of synchrotron radiation enables detailed investigation of electronic band structure. Experimental band structure diagrams can be obtained for principal directions in the Brillouin zone.

In this paper, we report a comparative photoemission investigations of properties of MOCVD-grown $Ga_{1-x}In_xN$ and GaN. Investigated samples were prepared in the High Pressure Research Center, Polish Academy of Sciences in Warsaw, Poland. The epilayers of GaInN and GaN were grown by the MOCVD technique on the (0001) faces of bulk GaN crystals [3]. The X-ray photoelectron spectroscopy (XPS) study of $Ga_{1-x}In_xN$ layer surface subjected to Ar^+ ion sputtering was performed using the photoemission spectrometer ESCA-300 at LISE FUNDP in Namur, Belgium. The angle-resolved photoemission experiments for $Ga_{1-x}In_xN$ and GaN surfaces prepared by repeated cycles of Ar^+ ion sputtering and annealing at 600°C under UHV conditions, were carried out at the beamline 41 (MAX-I) in the synchrotron radiation laboratory MAX-lab, University of Lund, Sweden. Surface crystallinity assessment by low energy electron diffraction (LEED) indicated a hexagonal (1×1) symmetry of both surfaces. Surface morphology was studied by atomic force microscopy (AFM).

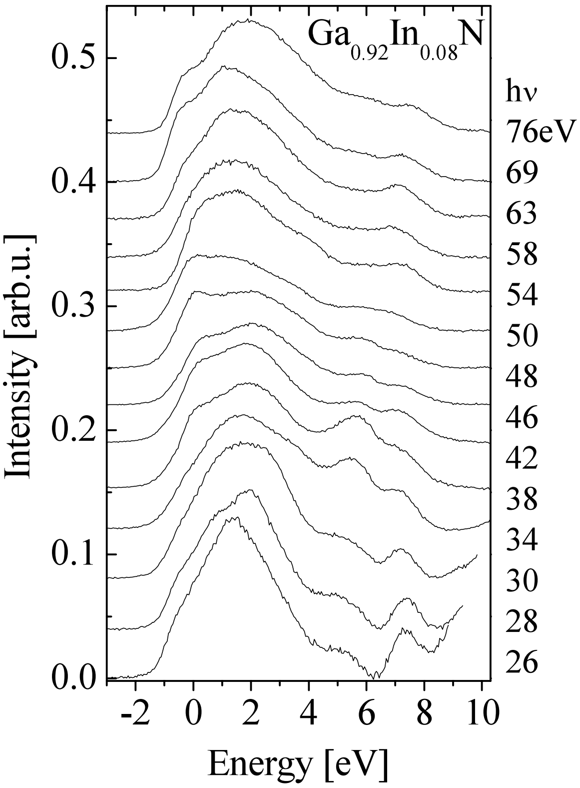

Figure 1. The set of normal-emission photoelectron energy distribution curves taken for $Ga_{0.92}In_{0.08}N$.

The XPS study of the surface subjected to Ar^+ ion sputtering was aimed at revealing the effect of such surface treatment on chemical composition of the surface region of the sample and checking if Ar^+ sputter cleaning could be applied to surfaces intended for photoemission measurements. The analysis of the relative intensities of In 3*d*, Ga 3*p*, and N 1*s* peaks showed that argon ion bombardment does not change significantly the relative contents of the layer constituents. Simultaneous efficient removal of the main contaminants (O and C) was observed during the sputtering procedure, proving that argon sputtering can be used as method for preparation of clean $Ga_{1-x}In_xN$ surfaces. Surface morphology study (by AFM) showed that such a process did not lead to marked destruction of the surface.

A comparative study of (0001) surfaces of $Ga_{0.92}In_{0.08}N$ and GaN was performed by means of angle-resolved photoemission spectroscopy. The sets of spectra taken in the normal emission mode (Fig. 1) enabled us to investigate the bands along the Γ-A direction in the Brillouin zone for both materials. An additional dispersionless feature at the valence band maximum was observed for $Ga_{0.92}In_{0.08}N$. The analysis based on comparison with available results of theoretical calculations [4,5] enabled us to relate this feature to the states pushed up from the top of the valence band, due to hybridization of In and N states.

Concluding:

- The electronic structures of $Ga_{0.92}In_{0.08}N$ and GaN epilayers were investigated by angle-resolved photoemission and the experimental band structures diagrams along the Γ-A direction were obtained.
- An additional dispersionless feature at the valence band maximum has been revealed for $Ga_{0.92}In_{0.08}N$ and it was interpreted as a manifestation of hybridization between In and N states.
- It was shown by means of X-ray photoemission spectroscopy and STM observations that Ar^+ ion bombardment can be used as a surface preparation method for $Ga_{1-x}In_xN$ epitaxial layers.

Acknowledgements:

This work was supported by KBN (Poland) project 2P03B 046 19 and by the European Commission - Access to Research Infrastructure action of the Improving Human Potential Programme (realized by MAX-lab facility in Lund). J.G. is supported by NFSR (Belgium) and F.M. by FRIA.

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