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Nitride nanowire surface modifications induced by chemical treatment and oxide layer deposition

B.J. Kowalski[1*], M. Sikora[2,3], A. Reszka[1], A. Wolska[1], A. Wierzbicka[1], S. Gieraltowska[1],
E. Partyka-Jankowska[2], M. Sobanska[1] and Z.R. Zytkiewicz[1]

[1]*Institute of Physics, Polish Academy of Sciences, 02668 Warsaw, Poland*
[2]*SOLARIS Centre, Jagiellonian University, 30392 Krakow, Poland*
[3]*Academic Centre for Materials and Nanotechnology, AGH University of Krakow, 30059, Krakow, Poland*

*e-mail: kowab@ifpan.edu.pl

Although the methods of inhibiting the detrimental impact of the surface modifications on the characteristics of semiconductor microdevices have been developed over the past decades, the methods of controlling surface conditions of semiconductor NWs, in particular those made of the group III nitrides, still remain an important and topical subject of research. We applied X-ray absorption spectroscopy (XAS) to assess chemical composition and atomic structure changes in the GaN nanowire surfaces caused by etching or by deposition of thin oxide layers.

The investigated GaN nanowires were grown by catalyst-free plasma-assisted molecular beam epitaxy (PA MBE) on silicon substrates. Four sets of samples were studied: as-grown samples, samples etched with HCl or KOH, samples covered with Al_xO_y and HfO_x layers of variable thickness. The oxide layers were deposited with use of the atomic layer deposition technique. XAS measurements were performed at PIRX beamline of SOLARIS. K edge of nitrogen and L edge of gallium were probed as a function of the angle - for the orientation between sample substrate and E vector of incident photon beam ranging from 0 (normal incidence) to 60 degrees.

The spectra acquired for all geometries and samples were normalized to the intensity of the incident beam to derive an effective XAS yield at Ga L and N K edges, which relates to chemical composition of nanowires and the thickness of oxide layers. Spectra collected at varying orientation were further normalized to the maximum on given absorption edge (the method used by M.G. Kibria et al. [1]). Such normalization gives a non-zero X-ray linear dichroism (XLD) signal in the energy range above the absorption edge and generates reliable results for quantitative spectrum analysis in the vicinity of the absorption edge maximum ("white line"). The amplitude of XLD is considered as semi-quantitative measure of structural anisotropy of GaN atomic structure.

The analysis of XAS and XLD spectra led us to the following conclusions:

- reduction of electron yield intensity enables assessment of the thickness of the oxide layers even for the thinnest coverages (below 5 nm),
- deposition of the oxide layers on GaN nanowires leads to reducing of the anisotropy of the GaN crystal structure in the interface layer,
- changes in the XLD and XAS amplitudes for the etched surfaces of GaN nanowires can be interpreted as a manifestation of removing nitrogen atoms from the surface and lowering the surface structural anisotropy of etched nanowires (especially with KOH).

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References

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