Scanning Photoelectron Microscopy of GaN Thin Films Grown on Silicon

R. Graupner[1], Qi Ye[2], T. Warwick[1], E. Bourret-Courchesne[2]
[1]Advanced Light Source, Ernest Orlando Lawrence Berkeley National Laboratory, University of California, Berkeley, California 94720, USA
[2]Materials Research Division, Ernest Orlando Lawrence Berkeley National Laboratory, University of California, Berkeley, California 94720, USA

INTRODUCTION

GaN and related nitride semiconductors have attracted a great deal of attention in view of their use for optoelectonic devices in the blue-green spectral regions (e.g. light emitting diodes and laser diodes). Sapphire is usually used as a substrate material. To combine GaN with conventional silicon technology, growth of GaN directly on Si would be desirable. However, nucleation of GaN on Si presents a major challenge, due to its large lattice-mismatch (17 %), different thermal expansion coefficient, and the ease of formation of silicon nitride. We therefore investigated a GaN thin film grown at high temperature on a Si (111) surface without buffer layer using MOCVD.

The main questions we were interested in was imaging the chemical composition of the sample. The Scanning Photoelectron Microscope (SPEM) at beamline 7.0.1.1 is well suited for this kind of experiment [1]. It measures spatially resolved chemical composition by scanning a focussed x-ray spot over the sample surface, recording the intensity of photoelectrons emitted out of characteristic core levels. Electron spectra are then measured at selected regions on the sample for detailed analysis. The lateral resolution of this instrument is presently about 300 nm.

Results

Figure 1 shows an image (40 μm × 40 μm) taken on the center of the sample. For this image the emssion of the Ga 3d core levels was recorded using a photon energy of 550 eV. As the analyzer collects electrons at grazing emission, topographical information can be obtained from the images. In Fig. 1 hills are visible. Those in the upper right part of the image appear more dark. XPS Survey spectra, taken at different locations on the sample surface (A-E, as indicated in Fig. 1) are shown in Fig. 2. By comparing the peak areas for the Ga 3d and the N 1s peak, it is evident that the Ga/N-ratio differs for different positions on the sample. Moreover, Si is visible in the spectra as indicated by the appearance of the Si 2s core level at a binding energy of 150 eV. An image, recorded by using the emission from the Si 2p core level is shown in Fig. 3. This image has been corrected for topographical artefacts, showing the true distribution of Si on the sample surface. By comparison to Fig. 1, it is evident that the Si signal is not due to emission from the substrate material through holes in a GaN film that is not completely closed. Instead the maximum Si signal is recorded on the hills. This indicates a segregation of Si to the sample surface. Furthermore, the smallest Ga/N-ratio is measured at the regions showing the highest Si content which indicates that Si is present on the surface in the form of SiN.

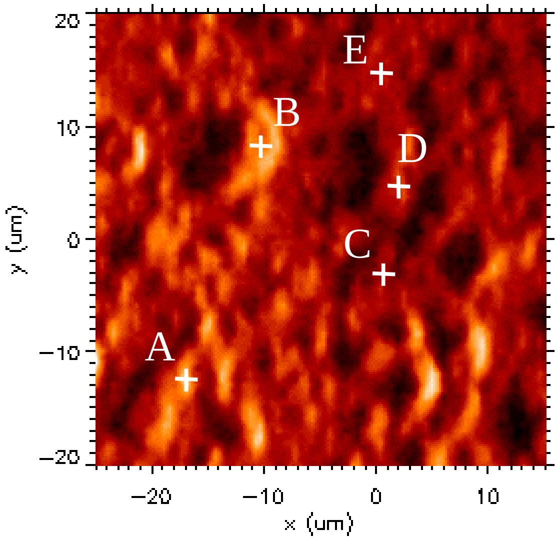

Figure 1. Ga 3d image of a GaN thin film grown on a silicon (111) surface (hν=550 eV) The letters indicate locations on the sample surface where electon spectra were recorded (see Fig. 2).

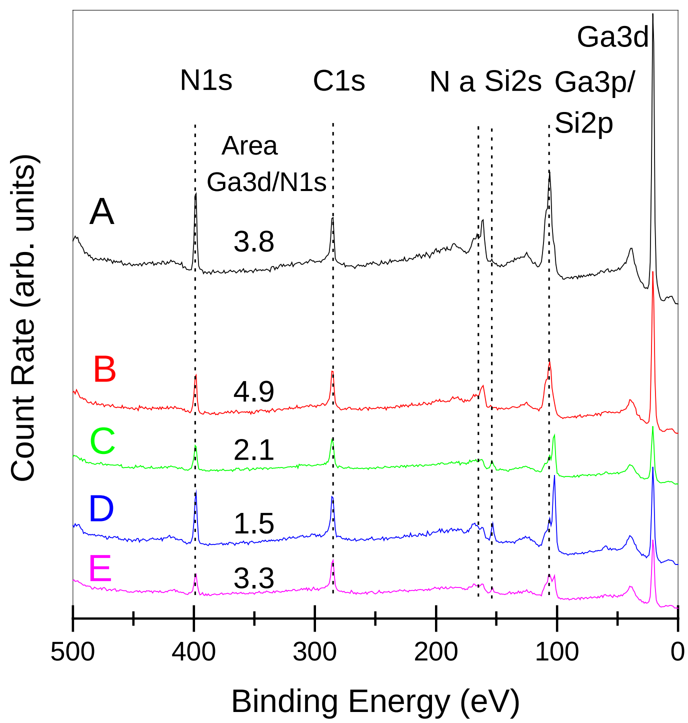

Figure 2. Survey spectra taken at different locations on the sample surface as indicated in Fig. 1.

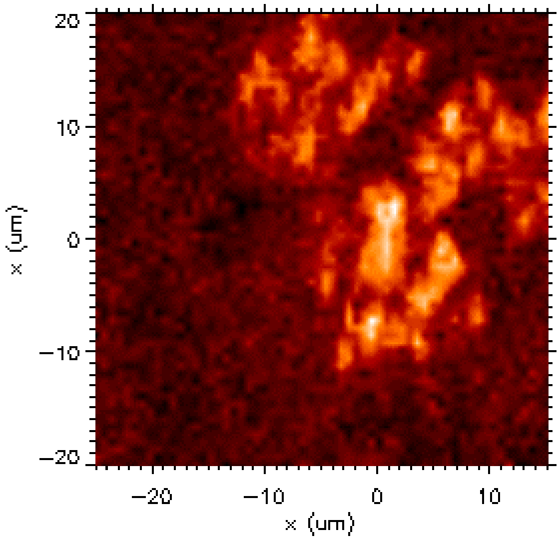

Figure 3. Si 2p image of the GaN thin film. The image has been corrected for topographical artefacts.

References

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Principal investigators: Edith Bourret-Courchesne, Materials Sciences Division, Lawrence Berkeley Laboratory.
e-mail: EDBourret@lbl.gov. Telephone: (510)-486-5553
T. Warwick, Advanced Light Source, Lawrence Berkeley National Laboratory.
e-mail: T_Warwick@lbl.gov. Telephone: (510)-486-5819