Scanning transmission electron microscopy (STEM) at low electron energies is a well-suited technique to achieve sensitive material contrast in the high-angle annular dark-field (HAADF) mode where contrast is attributed to incoherently scattered electrons. HAADF STEM can be exploited for sample thickness determination and composition analysis [1]. Transmission electron backscattered diffraction (t-EBSD) patterns were recently recorded from a thin specimen by a detector placed laterally to the tilted sample [2]. In our study the detector was placed on-axis below the sample and coherent electron scattering at energies up to 30 keV was analysed which yields axial Bragg-diffraction patterns with Kikuchi lines.

A FEI Strata 400S scanning electron microscope equipped with a segmented semiconductor STEM detector was used. A conventional imaging plate (IP) was inserted below the sample as a detector. The sample consists of a GaN layer with 140 nm thickness on a 120 nm AlN layer epitaxially grown on a Si(111) substrate. A TEM sample with a thickness of 120 nm was prepared by focused-ion-beam milling.

Figure 1 shows a 25 keV HAADF STEM cross-section image of the sample. Dislocations and columnar regions (indicated by dashed lines) with slightly different intensities can be seen in the GaN layer. A tilt series was recorded which shows changes and even contrast inversion within the GaN layer which is a strong indication for coherent scattering.

Figure 2 shows a transmitted on-axis IP-image taken at 25 keV at the position marked by a cross in Figure 1. Figure 2a depicts the illuminated area with the STEM detector segments marked by circles. Kikuchi lines are visible on the whole detector area which can be identified by comparison with simulated EBSD patterns. Diffraction patterns from different positions along the GaN layer show a shift of Kikuchi lines due to orientation changes in the columnar layer. Figure 2b depicts the inner region of the diffraction pattern. A GaN [1-100] zone-axis pattern is identified by measuring the scattering angles for the Bragg reflections. This pattern also yields information on the first-order Laue zone and shows (0002) two-beam excitation condition.

Axial diffraction patterns recorded with IP reveal Bragg reflections and Kikuchi lines within the scattering range covered by the STEM detector. They provide information on the crystal structure of the sample and show that coherent scattering must be considered even at large scattering angles at low electron energies. Moreover, the diffraction pattern shows the local orientation and excitation condition of the sample.

References

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Fig. 1: 25 keV HAADF STEM cross-section image with dislocations marked by arrows and columnar regions separated by dashed lines. The cross indicates the position where the diffraction pattern in Figure 2 was taken. The sample was covered with a Pt/C-layer for protection during FIB milling.

Fig. 2: a) Diffraction pattern taken at marked position in Figure 1 at 25 keV. The layout of the STEM detector is indicated by dashed-line circles. b) Inner region of a) showing a diffraction pattern of GaN [1-100].