Type of presentation: Oral

IT-13-O-2698 A focused Xe^{+}-ion column for fast materials sputtering at high spatial resolution to carry out time-of-flight mass spectrometry with nanoscale precision within a scanning electron microscope

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A unique combination of a high resolution scanning electron microscope (SEM) and a high current focused ion beam (FIB) using a plasma Xe ion source (FERA from TESCAN company) permits extremely high milling and material removal rates [1,2] while simultaneously being able to watch the process so that a precise end-point detection is at hand. Additional analytical add-ons such as energy dispersive x-ray detection (EDX), electron back-scatter diffraction (EBSD) and orthogonal Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS) (TOFWERK company) [3] permit a novel quality of correlated microscopies/spectroscopies.

For TOF-SIMS the high performance focused Xe-ion beam is used to remove the analyte material with the spatial resolution of a FIB. TOF-SIMS provides secondary ion imaging as well as depth profiling, so that a full three-dimensional isotopic images with better than 100 nm lateral resolution are possible.

Compared to a FIB based on Gallium primary ions, the Xenon ion source provides a better detection limit for most of the elements. A quantitative analysis has been demonstrated using a Xe plasma source for material sputtering and alkali elements, such as Li, Na, K constituting the analyte [4]. Detection limits below 2 ppm have been achieved for these species. Moreover, there is no interference when using Xe-FIB instead of Ga-FIB between the analyte and source Gallium ions for material that contain elements such as e.g. Ce, Ge, Ga. Therefore the Xe-FIB is more suitable e.g. for the analysis of important and widely used semiconductor materials and compounds such as SiGe, (In)GaAs and (In, Al)GaN.

Performance of the TOF-SIMS instrument relying on Xe-FIB materials removal has been demonstrated on samples with light-emitting-diode (LED) structures composed of GaN with InGaN Quantum Wells (QWs). A stack of five QWs, each with a thickness of 2.4 nm has successfully been detected (Fig. 1). The focused e-beam of the SEM has been used during TOF-SIMS measurements to account for charge compensation. An analysis of a different LED layer stack showed that a comparably rough interlayer structure is present inside the multi-QWs as demonstrated by the monitoring of TOF-SIMS $^{27}Al^{+}$ intensity which is related to a covering AlGaN layer. A 3D reconstruction of an Al rich layer that covers the QWs is shown in Fig. 2.

References:

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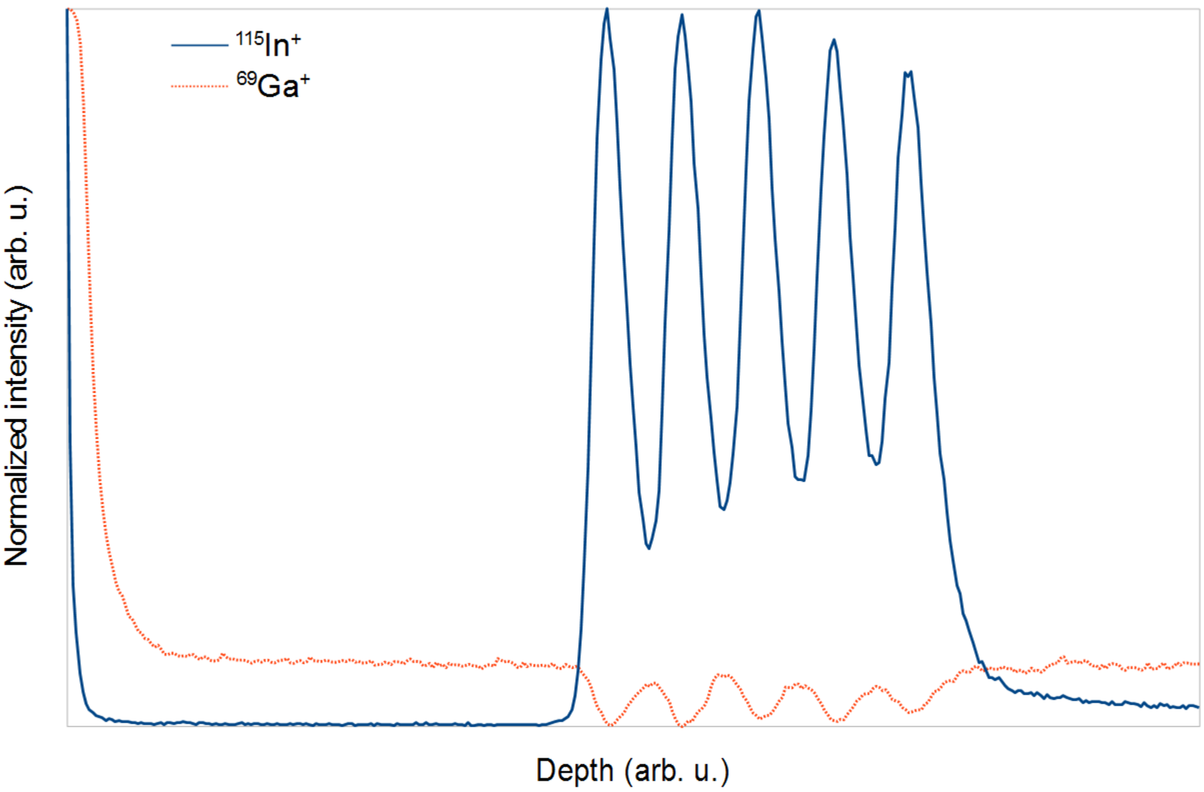

Fig. 1: TOF-SIMS depth profile of a GaN/InGaN multi-QW LED sample. Xe primary ion beam current of 550 pA at 30 kV was used for materials sputtering and SEM e-beam current of 1,2 nA at 10 kV was applied to account for charge compensation. Normalized depth profiles of $^{115}In^{+}$ and $^{69}Ga^{+}$ show well resolved 2.4 nm thick In rich quantum wells.

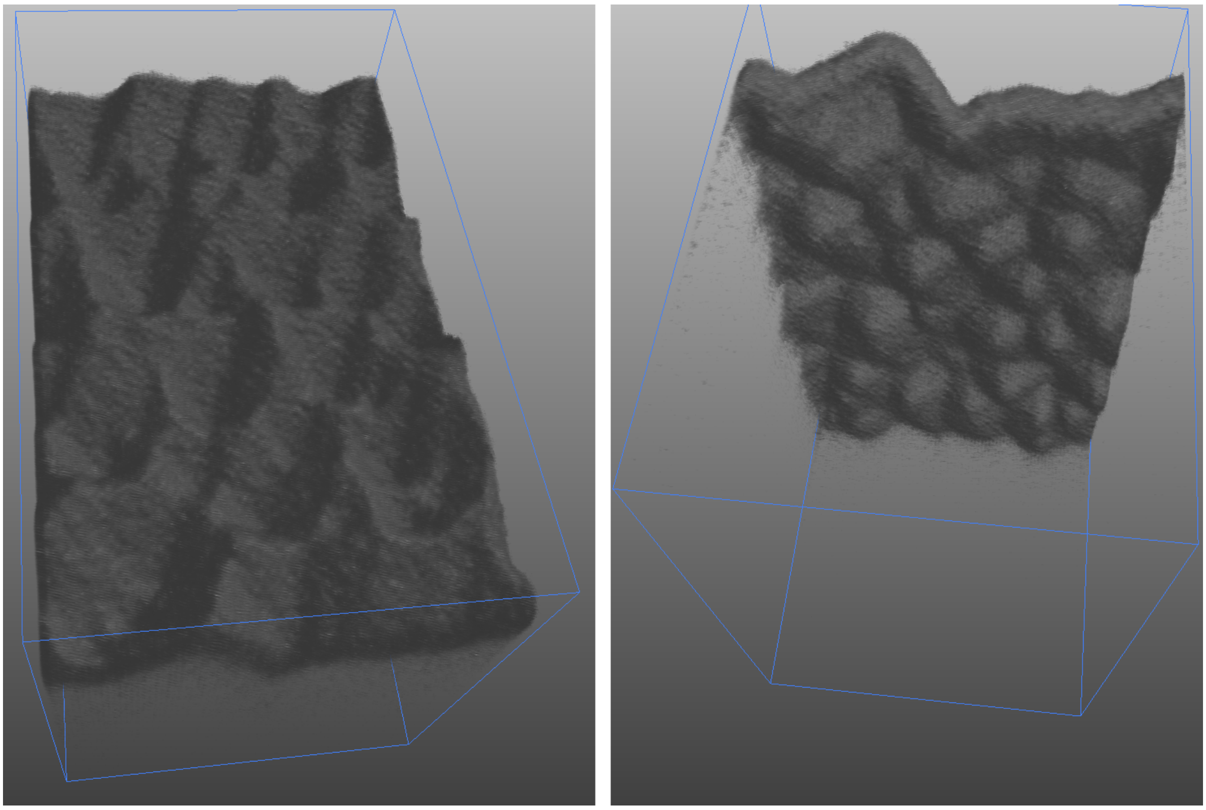

Fig. 2: 3D reconstruction of TOF-SIMS $^{27}Al^{+}$ signal that shows an Al rich layer covering InGaN/GaN QWs in LED structures. View from top (left) and bottom (right) are shown. The z-axis has been expanded 25 times to highlight the interfacial roughness. Field of view is 60 µm x 36 µm.