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# T- SEM: Quantitative Composition and Structure Analysis of FIB lamellae in SEM

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The understanding of semiconductor structures on the nanoscale mostly needs high-end analytical scanning transmission electron microscopy including respective STEM method combinations and complex specimen preparation. However, what if FIB-prepared specimens could be used for pre-screening and even some part of the analysis could be done in SEM already? What if correlative analysis methods for fast assessment of nanoscale properties and their impact on macroscopic (device) behavior could be usefully applied in SEM? We explore such alternatives investigating electron transparent FIB-lamellae in SEM, carrying out so-called analytical T-SEM.

Using TEM lamellae, the capabilities of quantitative composition analysis by Energy Dispersive X-ray Spectroscopy (EDS) in SEM were tested for III-V-based semiconductor layer structures and related to STEM data. In another T-SEM experiment, SEM EDS and transmission Kikuchi diffraction (TKD) in SEM were combined to understand the element composition and crystallographic properties of Cu interconnects in Si-based semiconductor nanostructures. We show that achieving useful results on the nanometer scale in a suitable amount of time, is possible in SEM by combining on-axis TKD [1] with an annular EDS detector [2] and specimen preparation of electron transparent specimens by FIB.

The first example shows EDS of AlGaN based LEDs prepared in cross-section by a standard lift out technique and investigated by EDS in SEM. Quantitative EDS analysis of the composition of MOCVD-grown LED layers, including the Ga grading content as well as Al depletion and Ga segregation triggered by morphological defects and influencing LED properties, was carried out based on the Zeta-factor method [3] (Figure 1) and related to data obtained in STEM.

Our second example demonstrates the combination of EDS and TKD of Si-based semiconductors (Figure 3). Features of interest, such as desired grain structure of the Cu interconnect and its surroundings as well as diffusion of elements other than Cu into the interconnect region are accessible. The thickness of this lamella was determined to be between 60 nm and 80 nm by tilt. The knowledge of the lamella thickness supports correct quantitative EDS using Zeta-factors. Furthermore, it tells us that the grains in the Cu plug are much smaller than the lamella thickness and may thus produce diffraction patterns overlapping with each other and with the silicon, which is also part of the lower plug structure, as is revealed by EDS.

In summary, EDS in SEM and the correlation with TKD is a powerful combination of techniques to support not only analysis in semiconductor technology but also in many other areas of materials research and life science. The characterization of complex mixtures containing crystalline and non-crystalline material, such as alloys with small precipitates, functional polymers, results of bio-mimetics and bio-mineralization will benefit from this analysis combination as well.

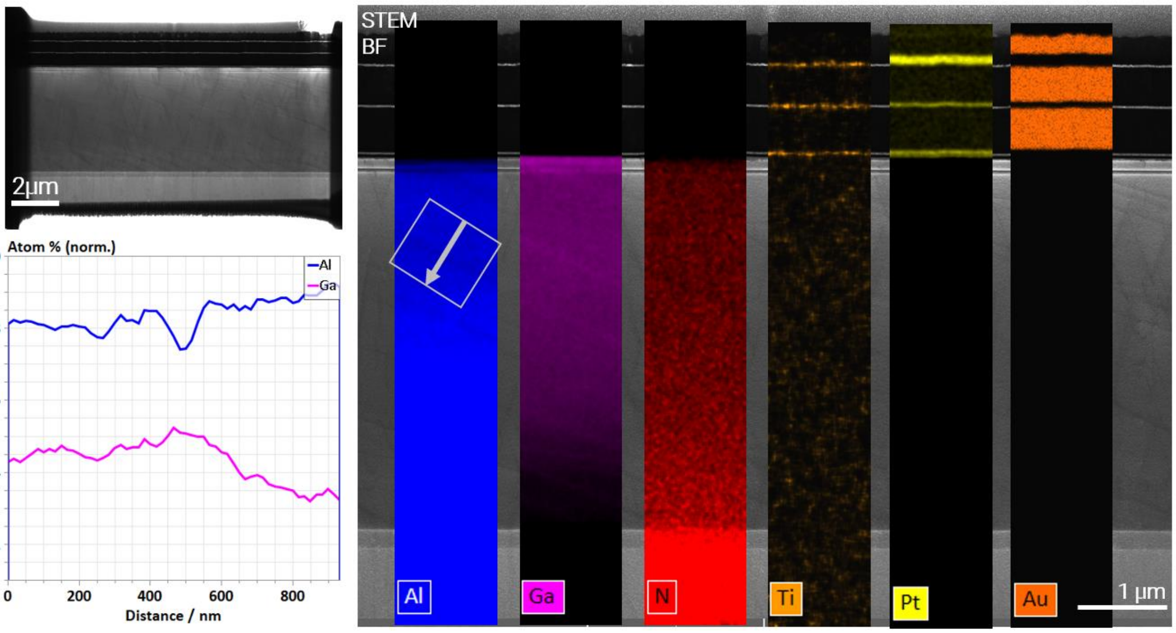


**Figure 1.** Left: FIB lamella as prepared and quantitative element profile through Al depletion / Ga segregation region (Zeta-factor method applied for quantitative EDS). Right: Overview with separated element distributions of one HyperMap, showing also the line region used to quantify the element profile on the left. For information: the nominal thickness of the three Ti layers on top is 30nm.

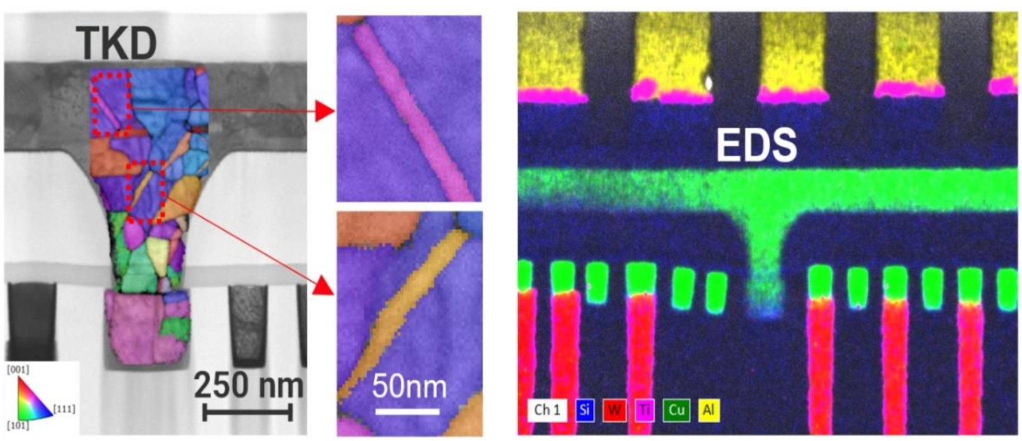


**Figure 2.** FIB lamella of Cu interconnect investigated by TKD and EDS. Only raw data are shown. The IPF map shows the Cu grain size distribution with the spatial resolution of a few nm. Cu grains and Si are overlapping in viewing direction at the lower end of the Cu interconnect, as shown in the EDS element line intensity map. Such overlaps must be considered in quantitative EDS and TKD analysis.

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