Quantitative Analysis of Internal Interfaces

Structural and quantitative analysis via high resolution STEM

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Introduction

The scope of the research project "Quantitative analysis of internal interfaces" is the high resolution analysis of internal interfaces in multilayer materials for electronic devices via aberration corrected STEM combined with HR EELS and EDX.
For this purpose, a variety of different approaches for both data acquisition and data analysis is consequently refined to provide reliable and reproducible datasets with high accuracy in both spatial and energetic resolution as well as in terms of quantitative reliability. Concomitantly, TEM sample preparation methods are sufficiently enhanced and modified to provide specimens with adequate quality.

Motivation

The detection and analysis of interfacial layers with few- or even sub-monolayer dimension in silicon based materials is one of the key topics of the project. Especially the transition area into the SiO_2 is of major interest, since the properties as well as the extent of this region can be crucial for device performance. Therefore, the EELS signals of the materials of interest are traced with high spatial and energetic resolution to yield detailed information about the chemical composition of the few atomic layers that form the interface between the two materials.
During data processing, various signal optimization and fit procedures are used to obtain the contributions of individual materials and their ELNES structure, finally leading to a more detailed comprehension of the exact composition of the transition region.

Evaluation of transition area between SiC and SiO_2

Wanted: Transition area between 4H-SiC and SiO_2
- **4H-SiC:** Four-layer hexagonal silicon carbide (4° offset, [0001])
- **SiO_2:** deposited
- N content at the interface (due to NO anneal)

Approach: Exposure of N edge in EELS signal, determination of contributing components in ELNES spectra
- Background subtraction, data fitting

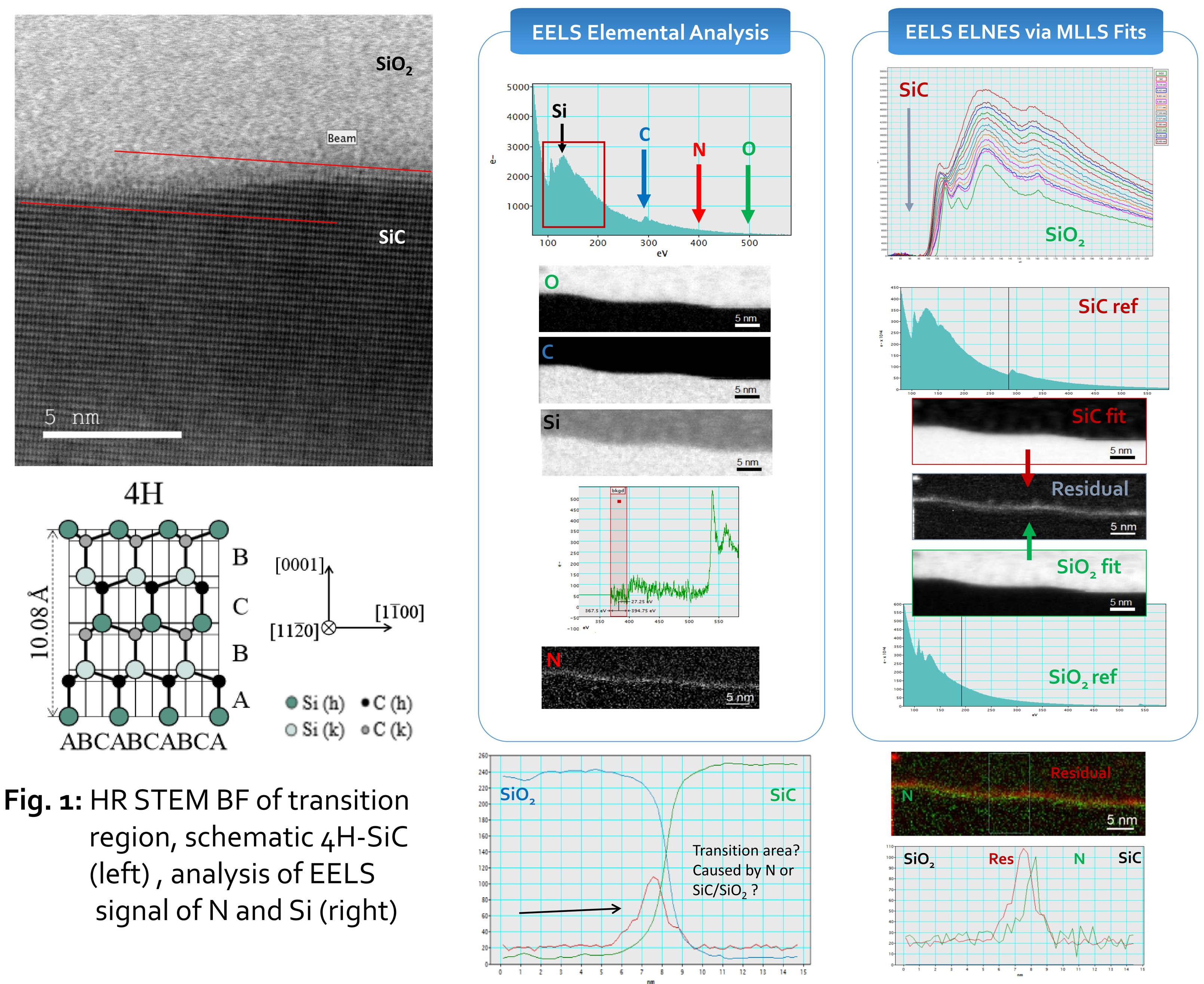

Fig. 1: HR STEM BF of transition region, schematic 4H-SiC (left), analysis of EELS signal of N and Si (right)

Transition area visible
- N can be localised reproducibly at the interface (< 1/3 monolayer!)
- Residual and N are not superimposed – residual shifted to SiO_2 side

➡ **Width of transition area : about 3.5 nm**

Evaluation of transition area between Si and SiO_2

Wanted: Transition area due to varying oxidation states of Si
- Nature of oxidation states
- Width of transition area

Approach: Comparison of ELNES signals of silicon and oxygen
- Background removal & noise suppression
- Fit procedures for identification of components

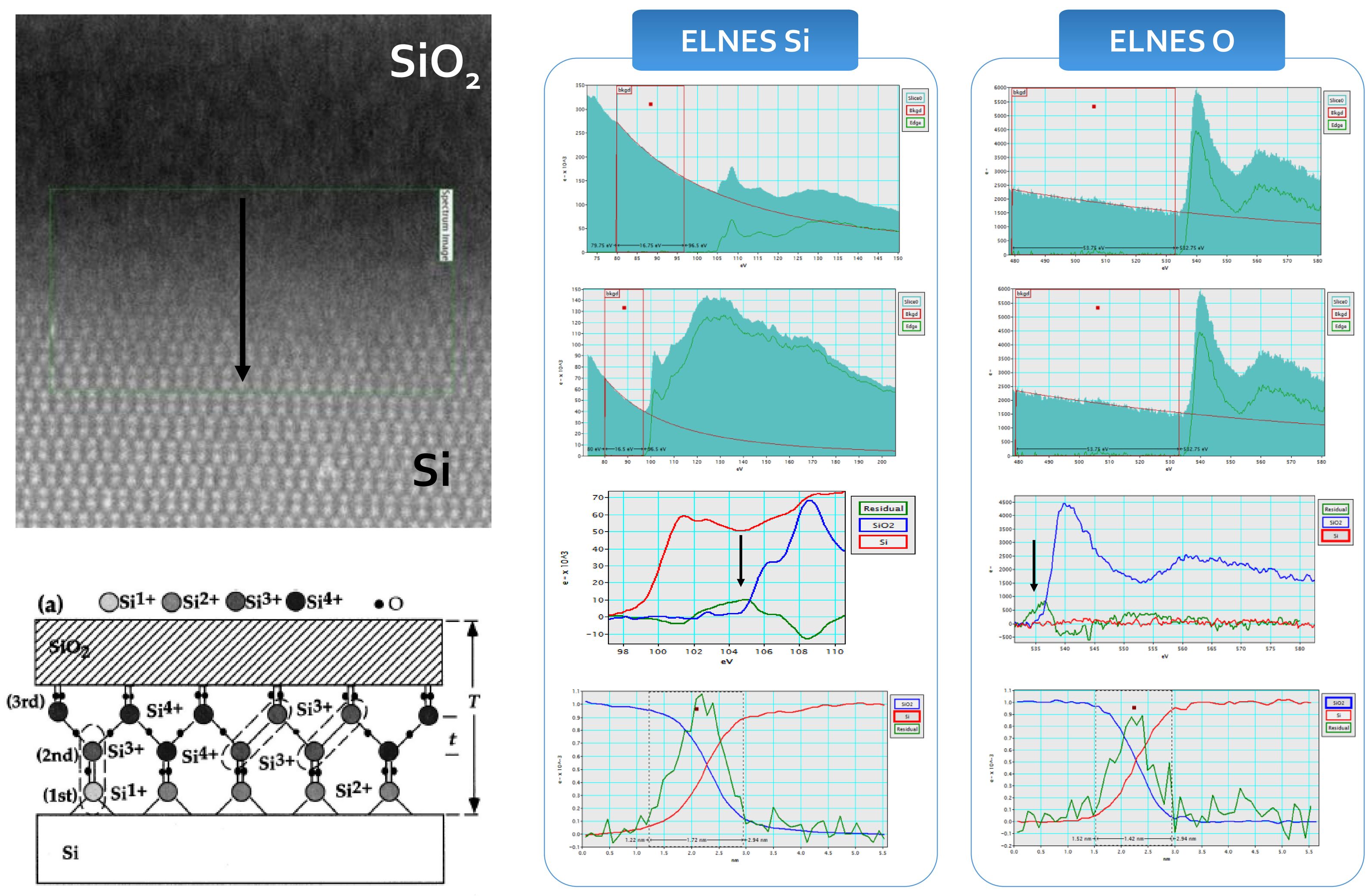

Fig.2: HR STEM HAADF of transition region, schematic of transition [1] (left) Analysis of ELNES signal of Si and O (right)

Formation of residual peaks:
- Residual of Si edge corresponds to maximum of $Si2^{+}$ peak [2]
- Oxygen edge correlates with shape of ELNES structure for $Si2^{+}$

➡ **Width of transition area: about 1,5 nm**

Conclusion

The advent of aberration corrected STEMs in combination with high performance EDX and EELS detectors vastly improves the performance of high resolution analytical TEM methods. However, techniques for evaluation and interpretation have to be evolved in parallel to utilize the potenial of the measurement equipment to an optimum extent. The advancement of these techniques for the qualitative and quantitative analysis is the core motivation for the presented project, focusing on interfacial layers for electronic devices.

References/ Acknowledgements

[1] Oh, PhysRevB (2001) 205310.
[2] Batson, Nature (1993) 366:727

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