Investigation of Interface Transition Chemistry in Semiconductor Structures via Monochromated EELS

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Introduction

Transition areas in multilayer assemblies used for electronic structures are of vital importance for the characteristics of the final devices. In this study, the interfacial region between the semiconductor substrate and the oxide layer was studied with atomic resolution scanning transmission electron microscopy and monochromated electron energy-loss spectroscopy in order to gain insight in the structural morphology and the chemical composition of the interface and the appearance of interfacial layers formed during passivation procedures and/or oxide deposition.

Motivation

In the immediate vicinity of an interface, two (or more) materials that are joined there typically do not change abruptly. Instead, they rather pass through a number of transitional states before adopting their bulk form. At the interface between a semiconducting material and the oxide layer, these are usually various oxidation states. If an additional passivation layer is present, too, it can also contribute via compound formation. The detection and analysis of these transitional layers with few- or even sub-monolayer dimensions in silicon based materials is of major interest, since the properties as well as the extent of this region can be crucial for device performance.

Evaluation of transition area between Si and SiO_2

- Transition area from Si to SiO_2 can feature various intermediate oxidation states from Si^{1+} to Si^{4+} [1]
- Some oxidation states possess ELNES features that can be distinguished from bulk signal

> Monochromated measurements of ELNES signal of Si-$L_{2,3}$ and O-K
> Evaluation of data via ICA
> Width and shape of residual signal can be used to estimate composition of transitional region

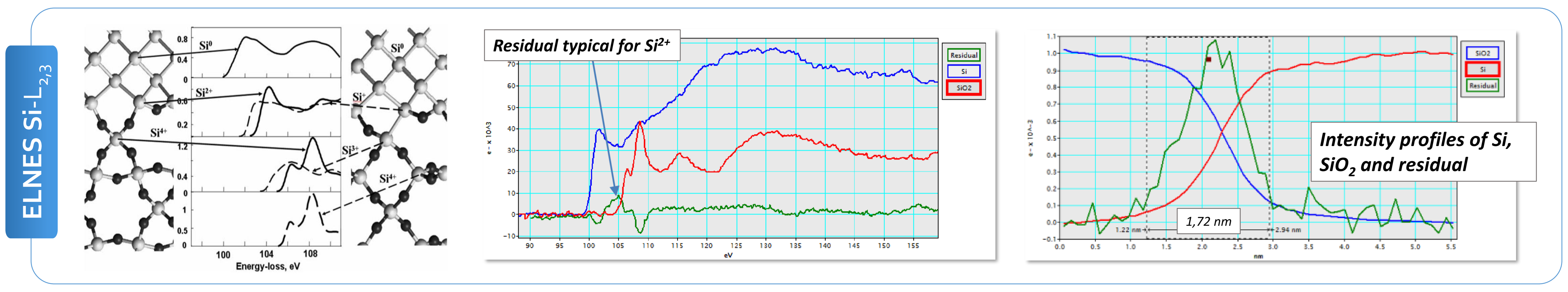


Fig.1: theoretical ELNES of Si oxidation states [2] (left), fit and residual signal (center) and intensity profiles (right) for Si-$L_{2,3}$ position

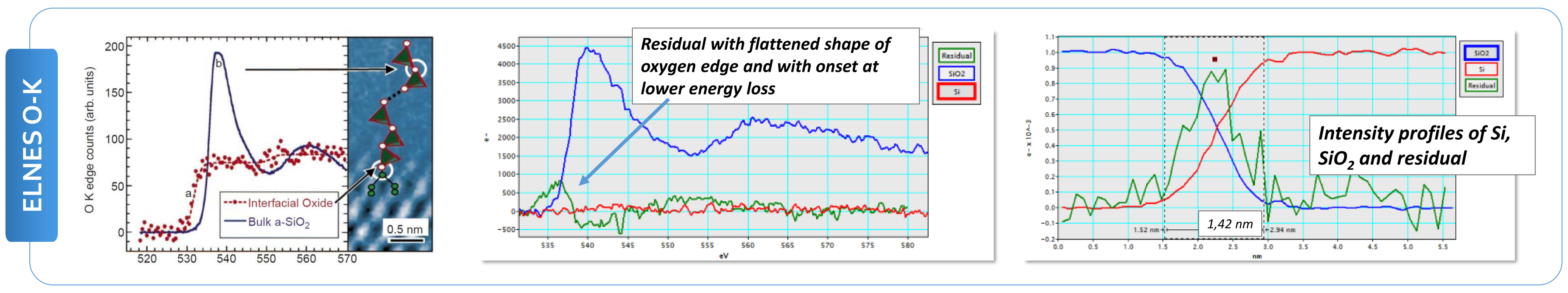
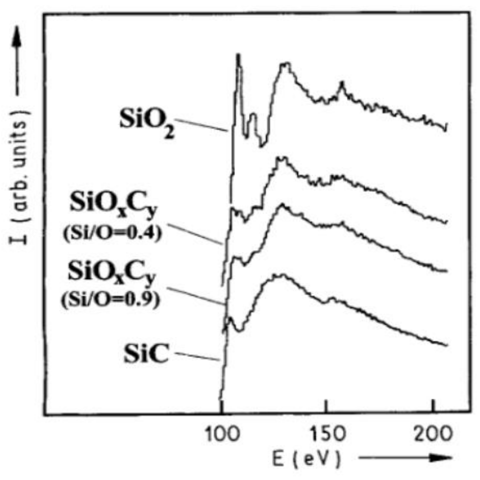


Fig.2: ELNES of O in SiO_2 and at interface [3], fit and residual signal (center) and intensity profiles (right) for O-K position

Evaluation of transition area between SiC and SiO_2

- Transition area from SiC to SiO_2 can feature various intermediate states resulting from intermixing of SiC and SiO_2 (see figure) or different oxidation states



- Additional N layer can be present due to annealing in passivating atmosphere
- Some intermediate states possess ELNES features that can be distinguished from bulk signal

> Measurements of ELNES signal of Si-$L_{2,3}$ and O-K
> Elemental mapping of N
> Evaluation of data via MLLS fits
> Width and shape of residual signal can be used to estimate thickness of transitional region

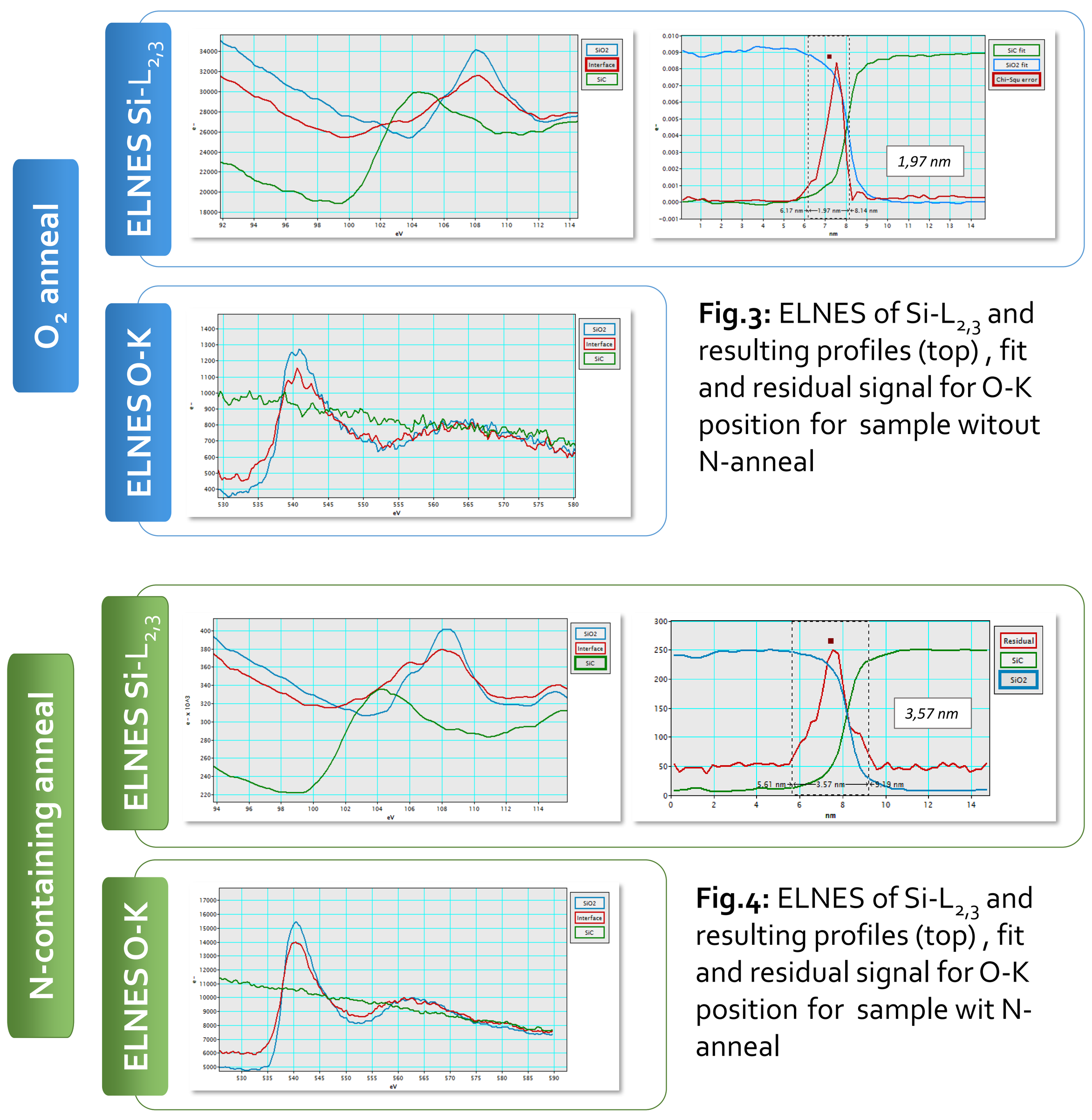
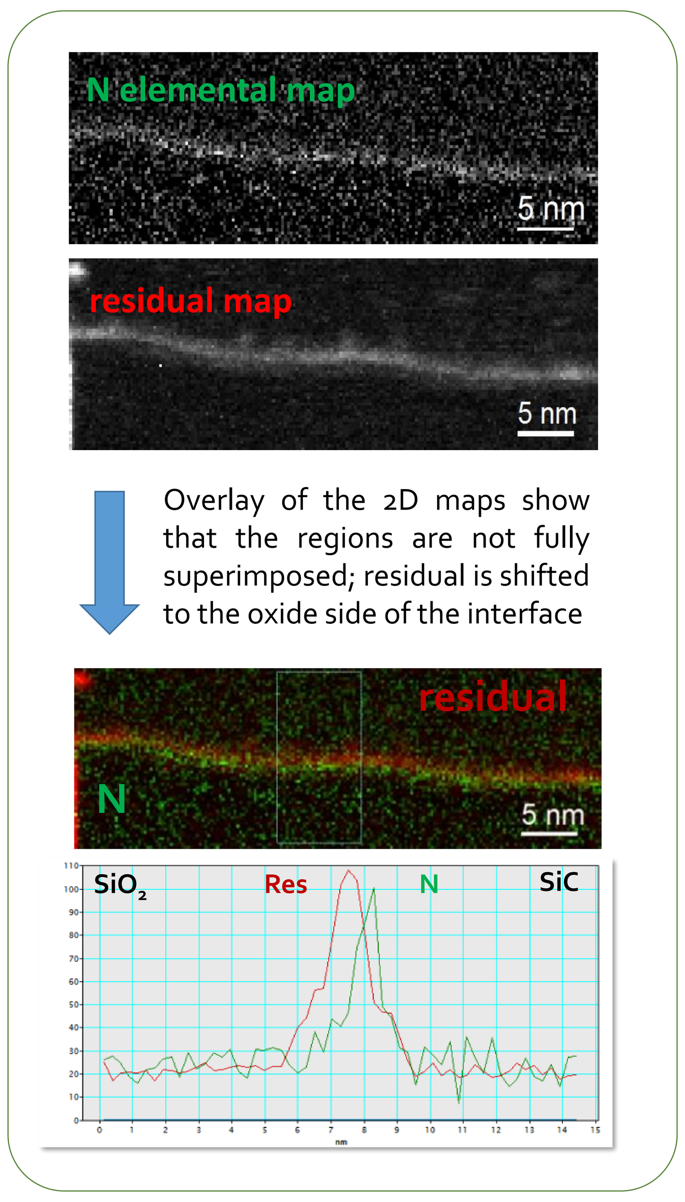


Fig.3: ELNES of Si-$L_{2,3}$ and resulting profiles (top), fit and residual signal for O-K position for sample witout N-anneal

Fig.4: ELNES of Si-$L_{2,3}$ and resulting profiles (top), fit and residual signal for O-K position for sample wit N-anneal



Overlay of the 2D maps show that the regions are not fully superimposed; residual is shifted to the oxide side of the interface

Conclusion

In this study we investigate the interface from Si and SiC into a SiO_2 layer. In order to determine the width and the chemical nature of the transition, the ELNES signals of both silicon and oxygen are traced with high spatial and energy resolution to yield detailed information about the chemical composition of the few atomic layers that form the interface between the two materials. In detailed analyses of the EELS signal from the transition layer between the semiconductor and SiO2, features in the fine structure of the Si $L_{2,3}$-edge and the O K-edge were found, which could not be explained as a superposition of the bulk signals. Independent components analysis (ICA) of monochromated EELS data revealed ELNES features at the interface typical for intermediate oxidation states of Si and O.

References/ Acknowledgements

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