Measuring buried interface roughness by electron tomography

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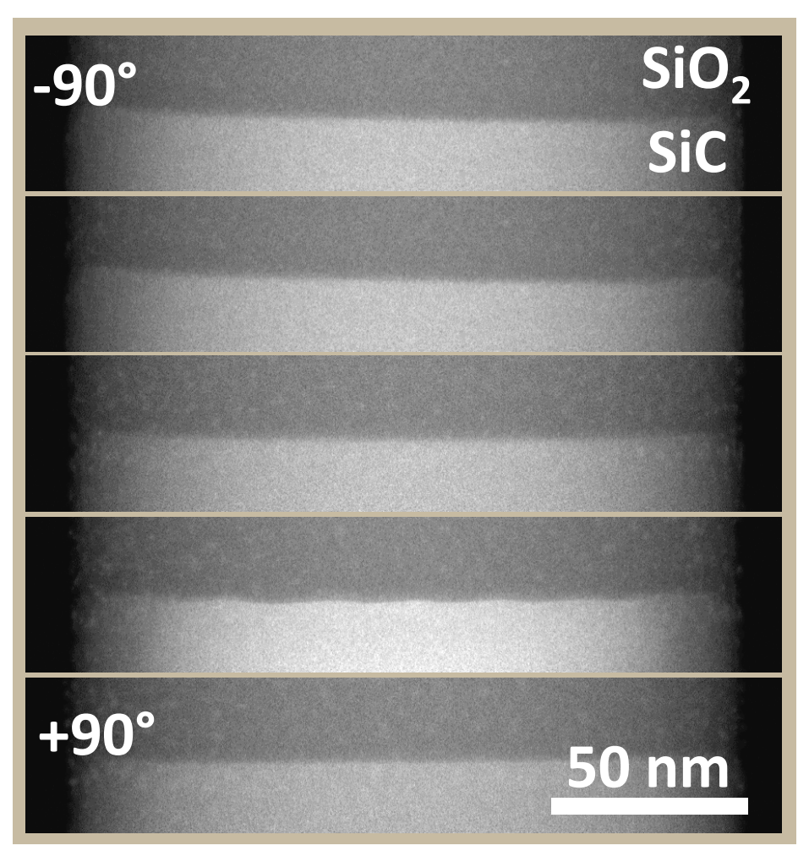
Introduction

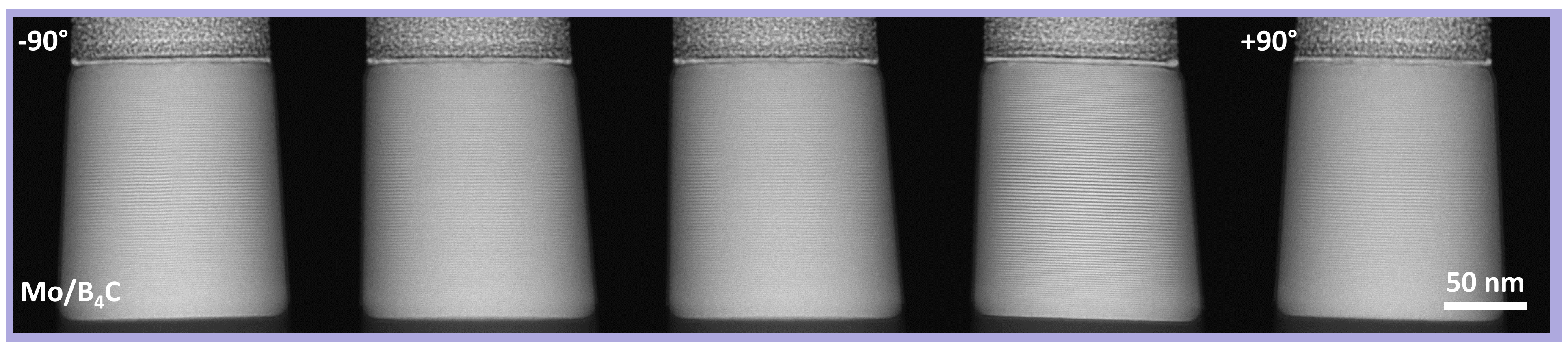
The roughness of surfaces and interfaces between different materials at a sub-nanometer scale is an important factor for the functionality of many materials and devices, examples are semiconductor devices or X-ray mirrors. On a local scale, atomic force microscopy (AFM) is usually the method of choice for measuring surface roughness, but AFM is unable to access buried interfaces. For imaging buried interfaces the transmission electron microscope (TEM) is an useful tool, but interface roughness is masked by the projection nature of TEM images. Electron tomography can overcome this limitation by reconstructing a 3D image of a sample for a tilt series of projections, using high-angle annular dark field (HAADF) scanning TEM (STEM).

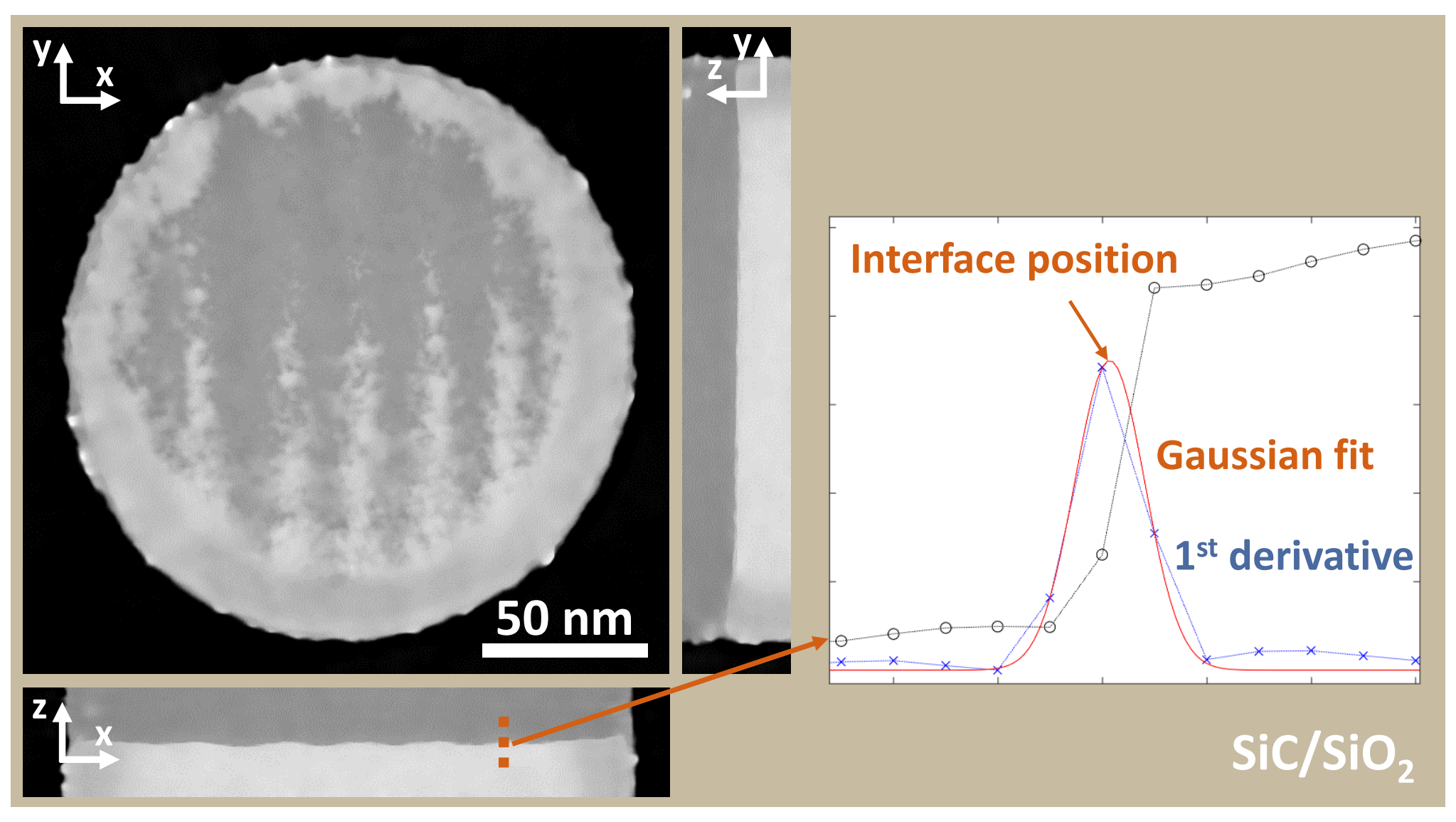
Materials and Methods



We investigate two materials by electron tomography: A SiC/SiO$_2$ interface and an X-ray mirror consisting of alternating Mo and B$_4$C layers.

For each material we acquire HAADF STEM tilt series over a range of 180° with a tilt step of 1°

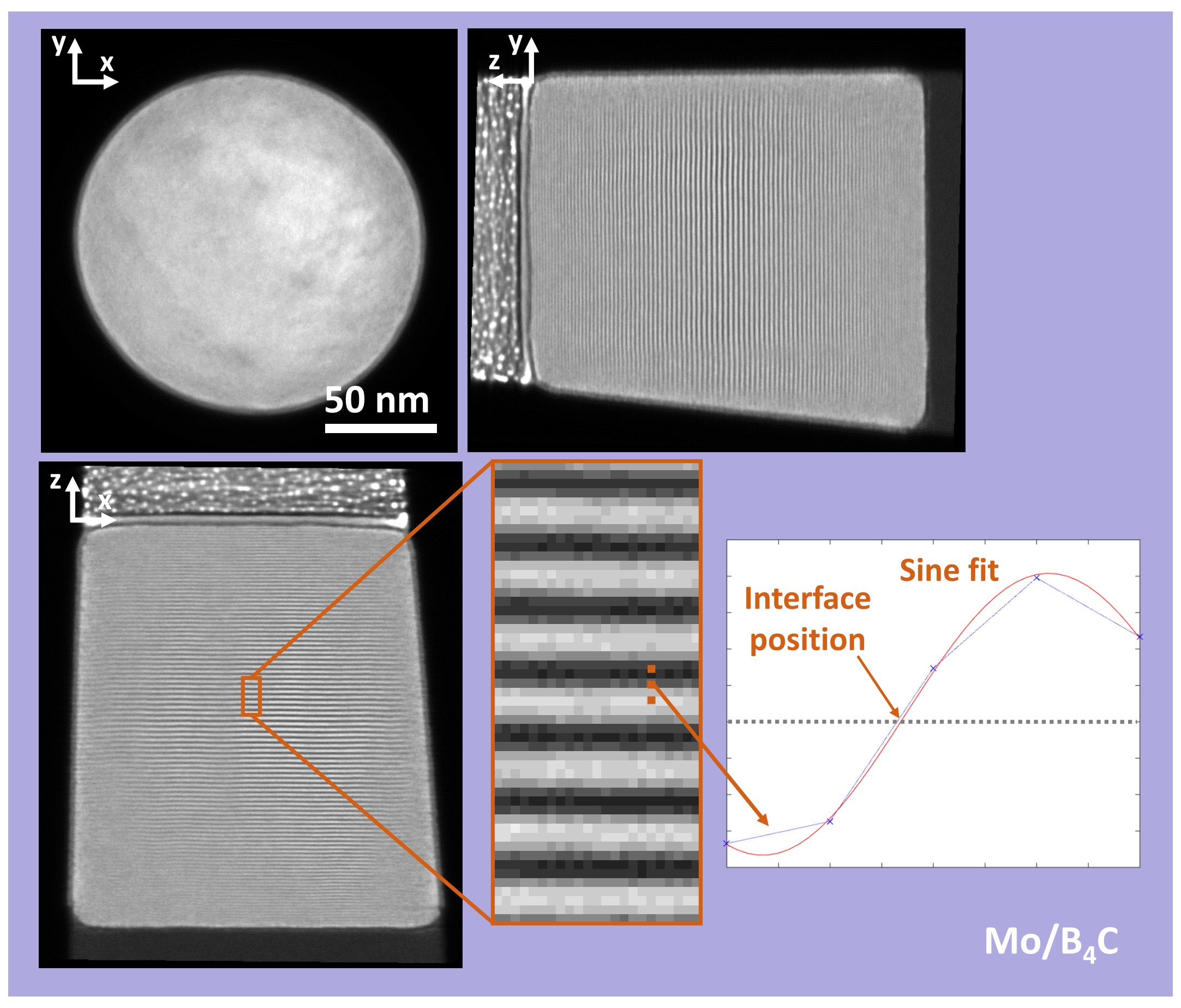




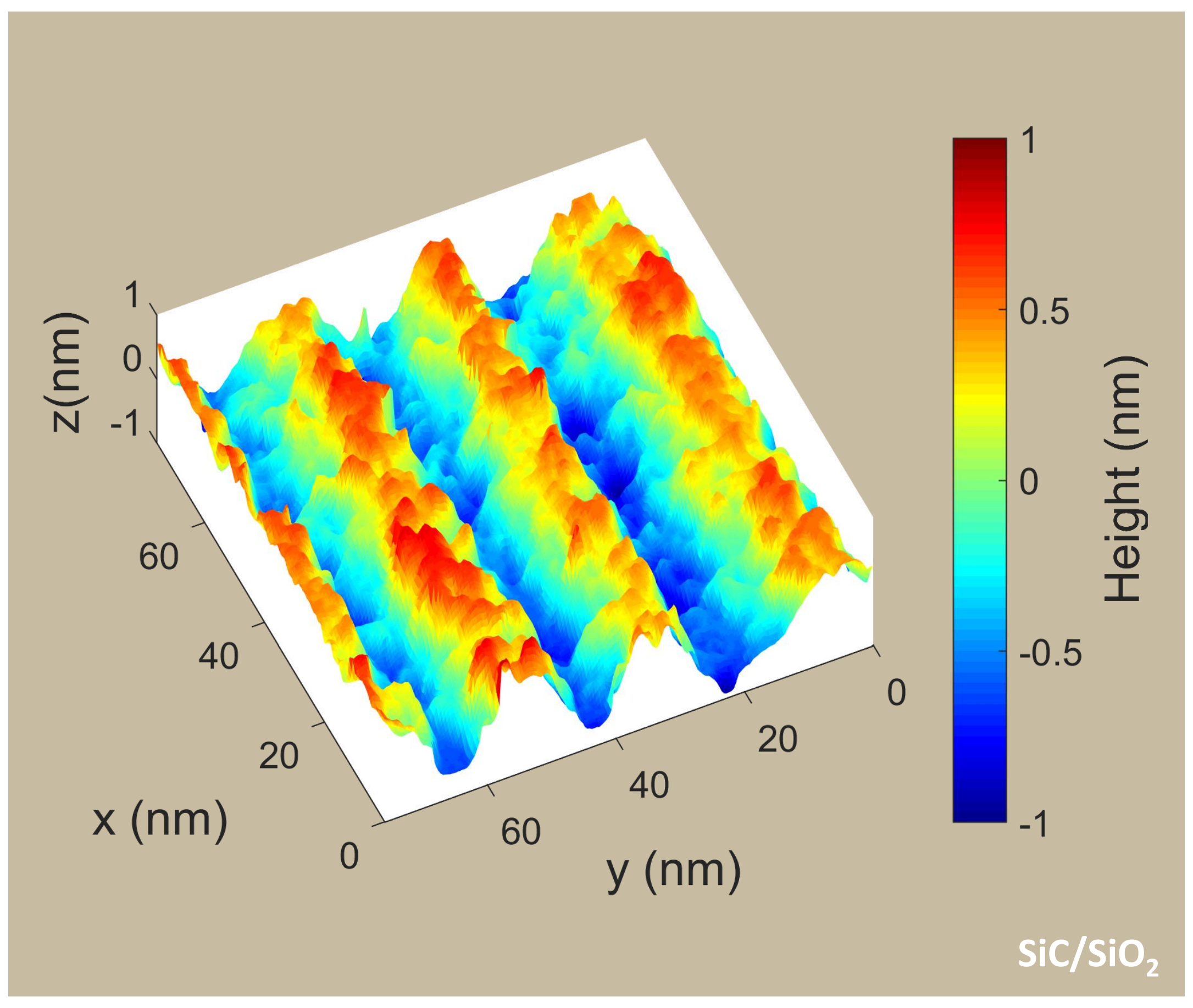
After reconstruction of the tilt series we determine the interface positions from 1D line profiles extracted perpendicular to the interface.

For the SiC/SiO$_2$ interface we calculate the first order derivative of the profile and fit a Gaussian to it, for the Mo/B$_4$C interfaces we fit a sine curve to the profile. The maximum of the Gaussian or the zero-crossing of the sine determine the interface position.

This is done for each xy-position to get the 2D contour of each interface.

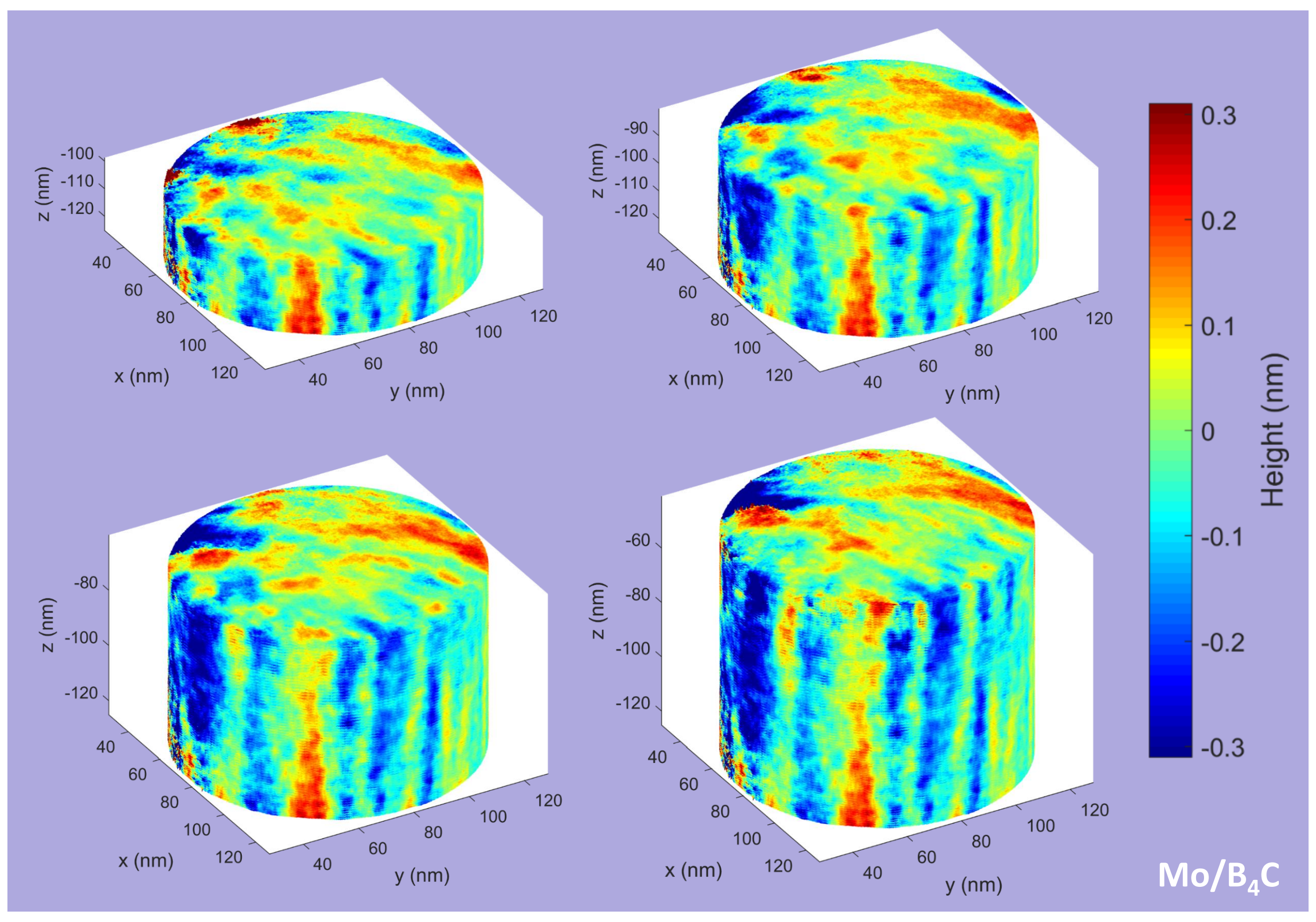


Results



The reconstructed SiC/SiO$_2$ interface clearly shows the typical step punching of ~5 SiC bilayers. Within the steps additional roughness is visible, but it is uncertain whether this is real or an artifact of data acquistion and processing.

For the Mo/B$_4$C interfaces roughness in the range of +/- 0.3 nm is observed, which is correlated between multiple neighboring layers.



Conclusion

- Electron tomography allows determining buried interface roughness with accuracy well in the sub-nm regime.
- Multiple interfaces can be investigated at once.
- The missing element is a reliable error estimation.

Acknowledgements

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