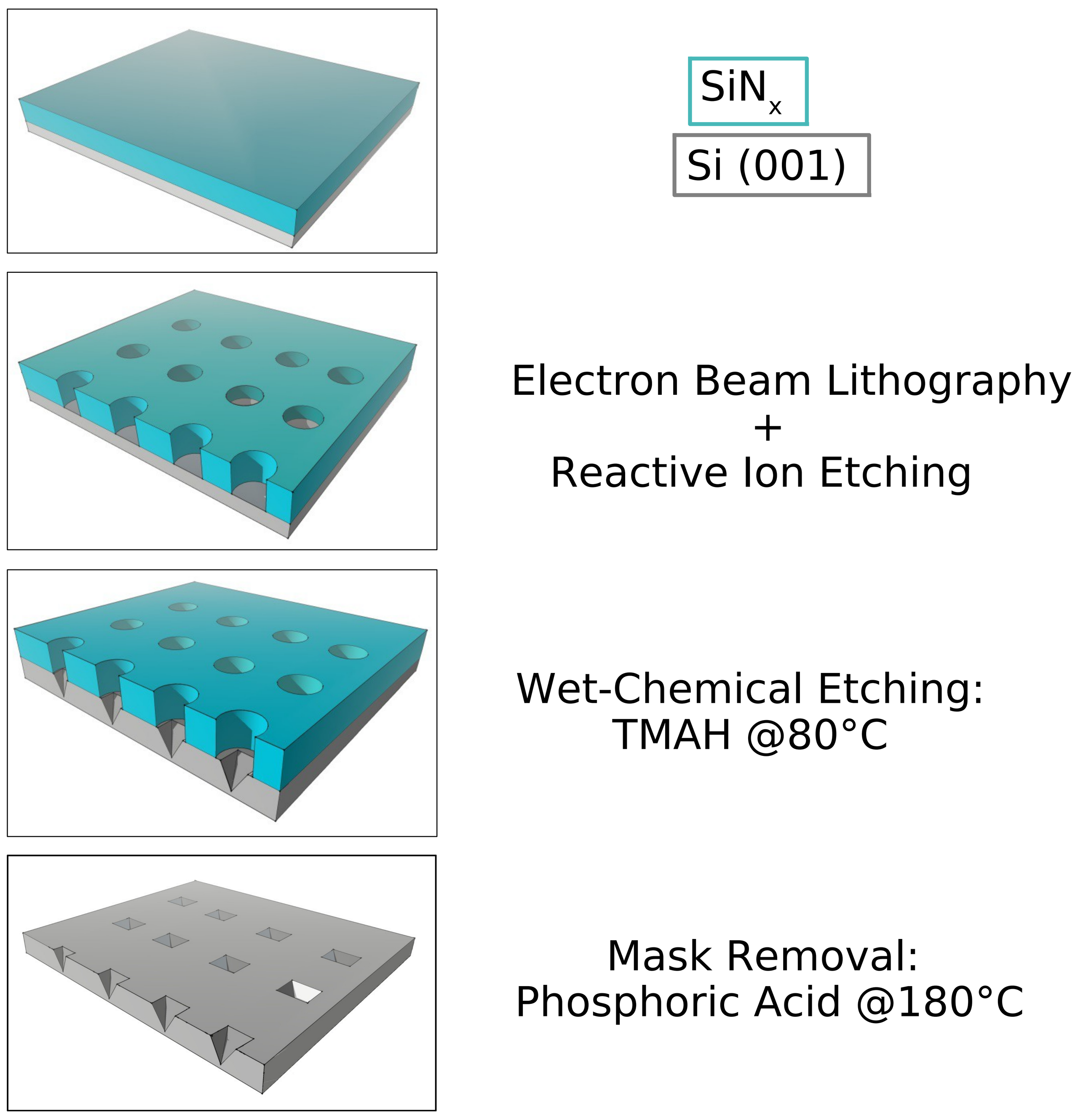
Dislocation engineering in SiGe on periodic and aperiodic Si(001) templates studied by fast scanning X-ray nanodiffraction

V. Mondiali[1], M. Bollani[2], S. Cecchi[1], M. Richard[3], T. Schulli[3], G. Chahine[3], D. Chrastina[1]
[1] L-NESS, Politecnico di Milano, Como, Italy
[2] IFN-CNR, L-NESS, Como, Italy
[3] ID01/ESRF, Grenoble, France

In the present work we exploit a suitable pit-patterning of a Si(001) substrate to influence the nucleation and the propagation of dislocations during epitaxial deposition of $Si_{1-x}Ge_x$ alloys, preferentially gettering segments along pit rows. Fast-scanning X-ray nanodiffraction microscopy is used to directly visualize the dislocation network in the SiGe film at the beginning of plastic relaxation. X-ray real-space diffracted intensity maps are compared to topographic atomic force microscopy images, in which crosshatch lines can be seen. The change in intensity distribution as a function of the incidence angle shows localized variations in strain within the SiGe film. These variations, which reflect the order imposed by the substrate pattern, are attributed to the presence of both bunches of dislocations and defect-free regions.

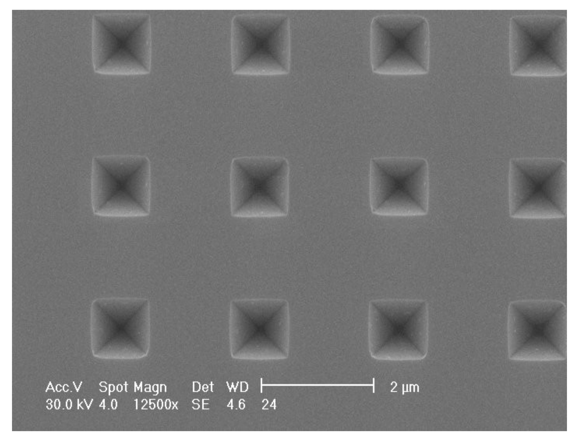
Bottom-up approach

- The Si(001) substrate is patterned with arrays of {111}-faceted pits aligned along the <110> directions.



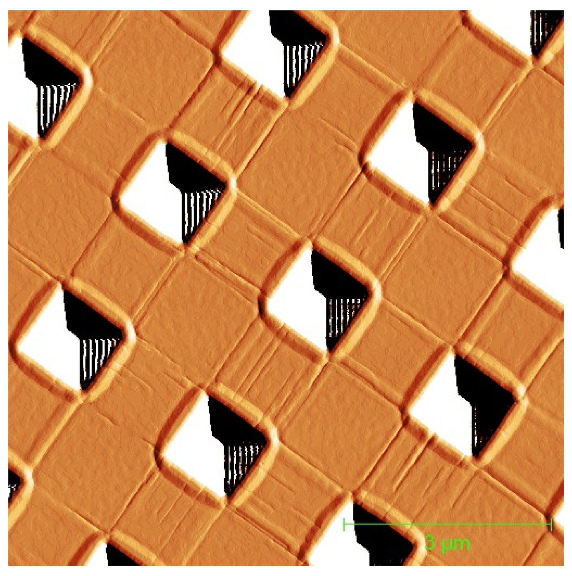
- A 250 nm $Si_{1-x}Ge_x$ alloy layer (Ge content of 16%–20%) is deposited by Low-Energy Plasma-Enhanced Chemical Vapor Deposition.

Sample characterization



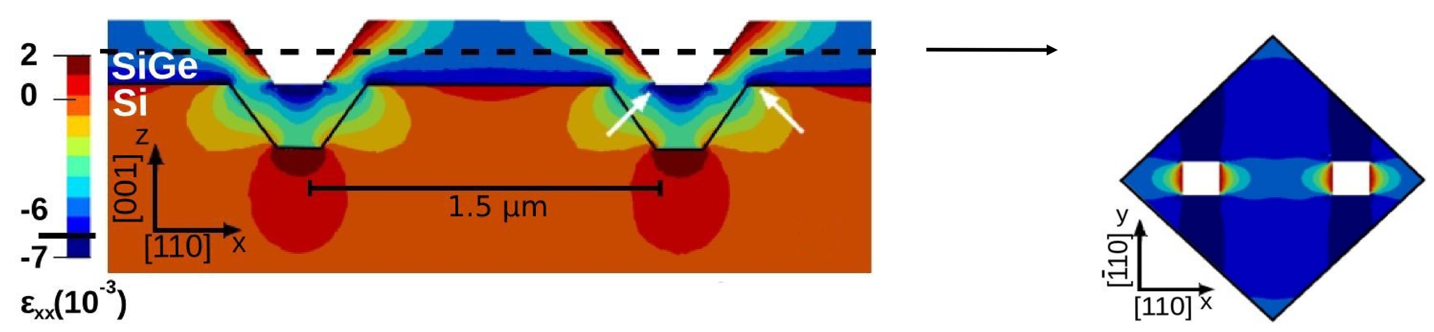
The SEM image shows a patterned substrate: a matrix of inverted {111} pits on a Si(001) substrate surface

The pit patterning perfectly influences the nucleation and the propagation of dislocations along the pit rows!



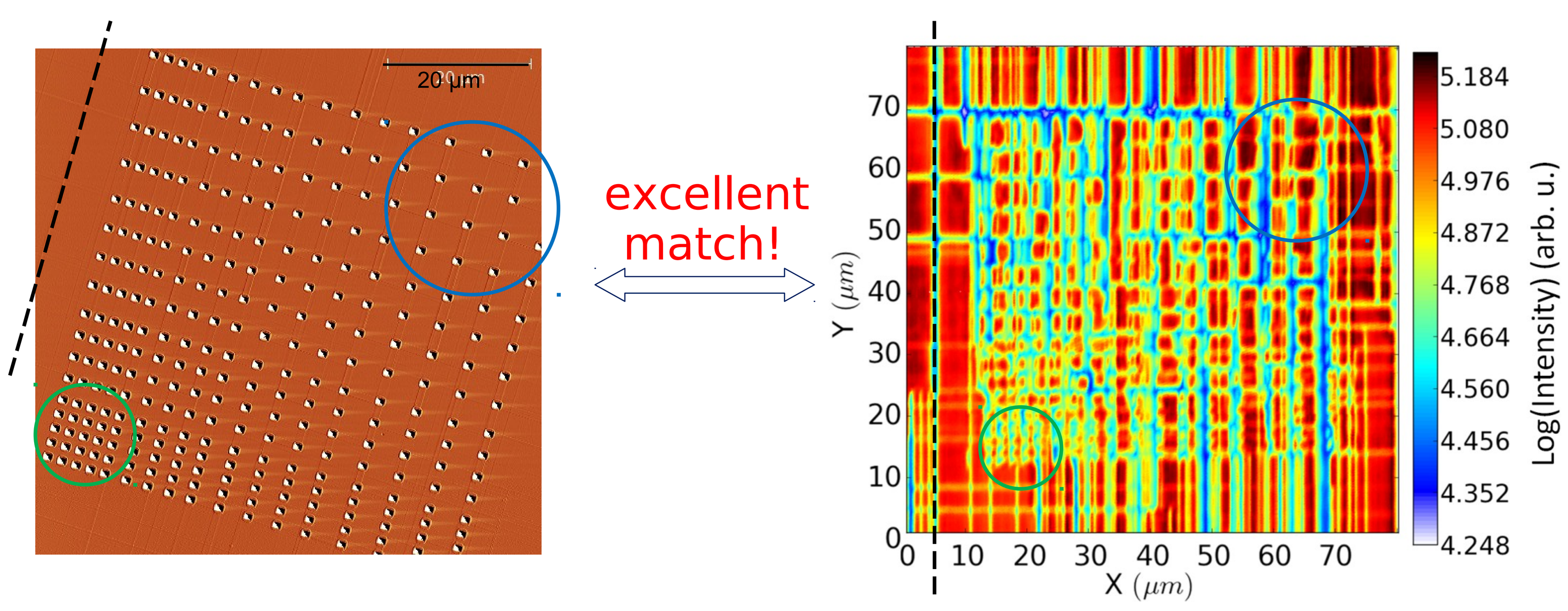
Tapping mode AFM image

FEM simulations have confirmed that the pit-patterning produces an inhomogeneous distribution in stress. The high strain sites are the preferential sites for dislocation nucleation in terms of energy minimization.

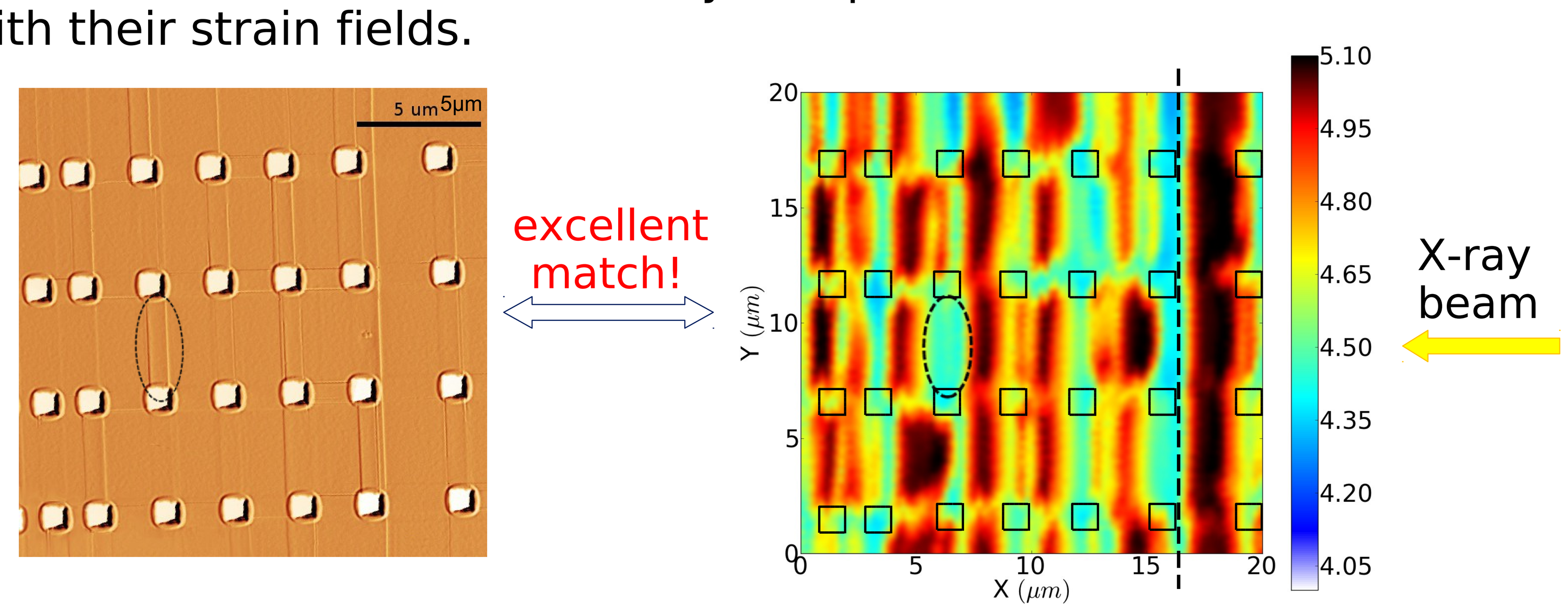


X-ray nanodiffraction analysis

Two-dimensional real-space map of the total diffracted intensity of the SiGe(113) Bragg peak is compared to the AFM image.

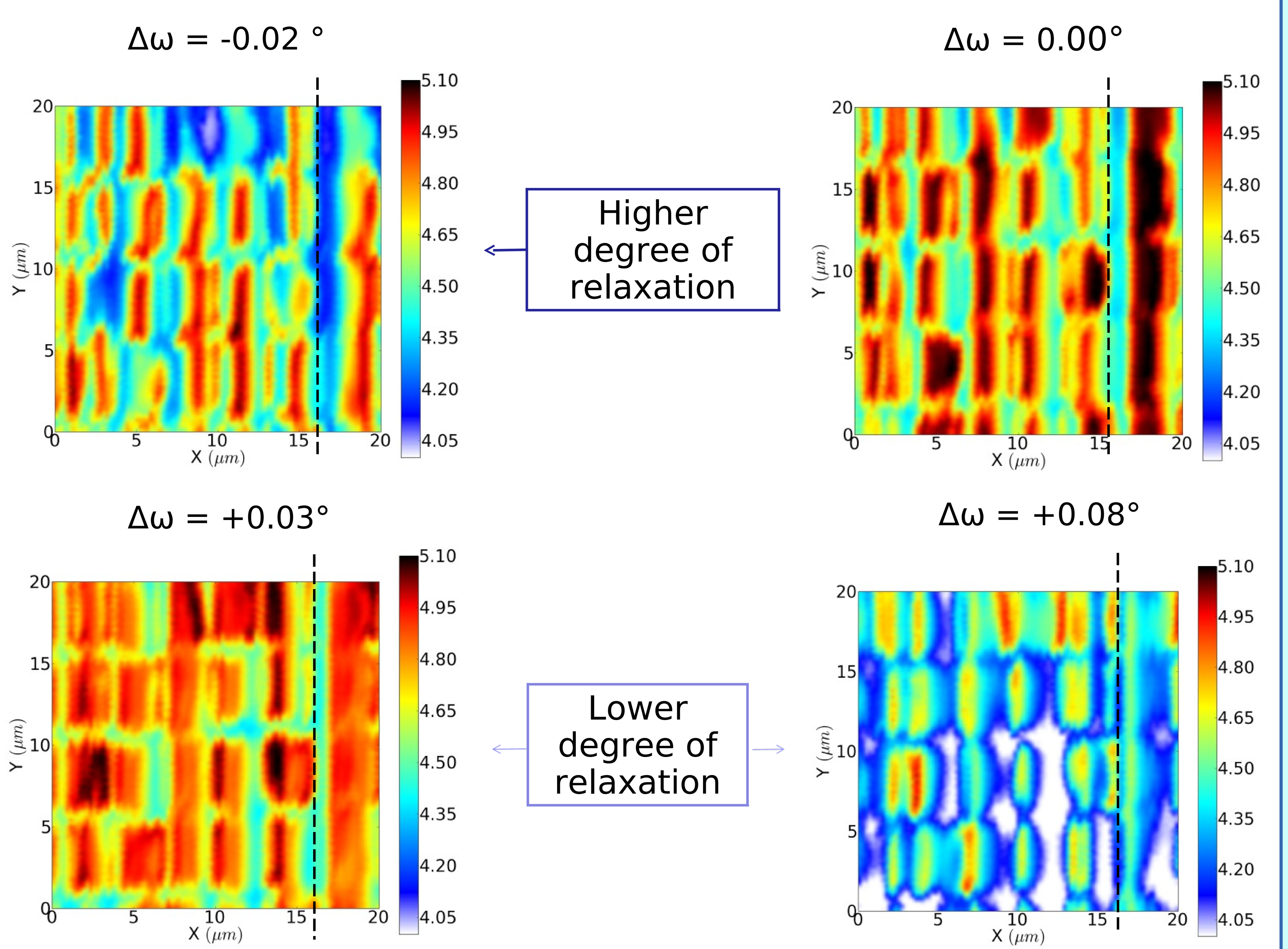


Dislocation are visible under appropriate diffraction conditions due to the local lattice tilts and alloy composition variations associated with their strain fields.



The measurement is only sensitive to the in-plane strain fields of dislocations running in the [1-10] direction.

X-ray intensity maps at different incidence angles



Defect lines can be identified over a broad range of incidence angles away from the Bragg peak.

Contact information

E-mail: valeria.mondiali@gmail.com

fondazione cariplo

References

J. G. Fiorenza, G. Braithwaite *et al.* (2004). Semicond. Sci. Technol. **19**, L4
M. Grydlik, F. Boioli *et al.* (2012). Appl. Phys. Lett. **101**, 013119
T. Etzelstorfer, M. J. Suess *et al.* (2014). J. Synchrotron Radiat. **21**, 111
V. Mondiali, M. Bollani *et al.* (2014). Appl. Phys. Lett. **104**, 021918
G. A. Chahine, M.-I. Richard et al. (2014). J. Appl. Cryst. **47**, 762

This work was supported by Fondazione Cariplo, grant DefCon4 2011-0331.