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Local Strain Measurements at Dislocations, Disclinations and Domain Boundaries.

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We present the state of the art in strain mapping at the nanoscale using aberration-corrected high-resolution transmission electron microscopy, HRTEM and HAADF-STEM, and dark-field electron holography (DFEH) [1]. In particular, we will focus on the examination of localized strains around defects. A broader comparison of TEM strain mapping techniques can be found in a recent review [2].

High-resolution images can be analysed by geometric phase analysis (GPA) [3] or applying peak-finding routines to determine the positions of individual atomic columns. GPA is best adapted to measuring the deformation of the crystalline lattice, as the example concerning a five-fold twinned Pt nanoparticle will show (Figure 1). These star-shaped particles [4] have a disclination-like strain fields around their centres, as found for Au nanoparticles [5]. In multiferroic materials, peak-finding can be used to determine the relative displacements of atom columns within a unit cell [6]. The local polarization and strain can be mapped around dislocations and in the vicinity of domain walls (Figure 2).

DFEH was developed to measure strain over wide fields of view to high precision and nanometre spatial resolution. We have nevertheless been applying the technique to the study of quantum dots to relatively high resolution [7]. As with any TEM technique the samples are necessarily thin which allows some of the strain to be relaxed: the well-known thin film effect. In addition, dynamical scattering effects the strain information [8]. These issues will be addressed using a combination of finite-element modeling (FEM) and dynamical-scattering simulations.

This overview will, in addition, show results from the recently installed I2TEM microscope (Hitachi), an instrument specifically designed for DFEH experiments and aberration-corrected HRTEM over wide fields of view and for in-situ experiments (Figure 3).

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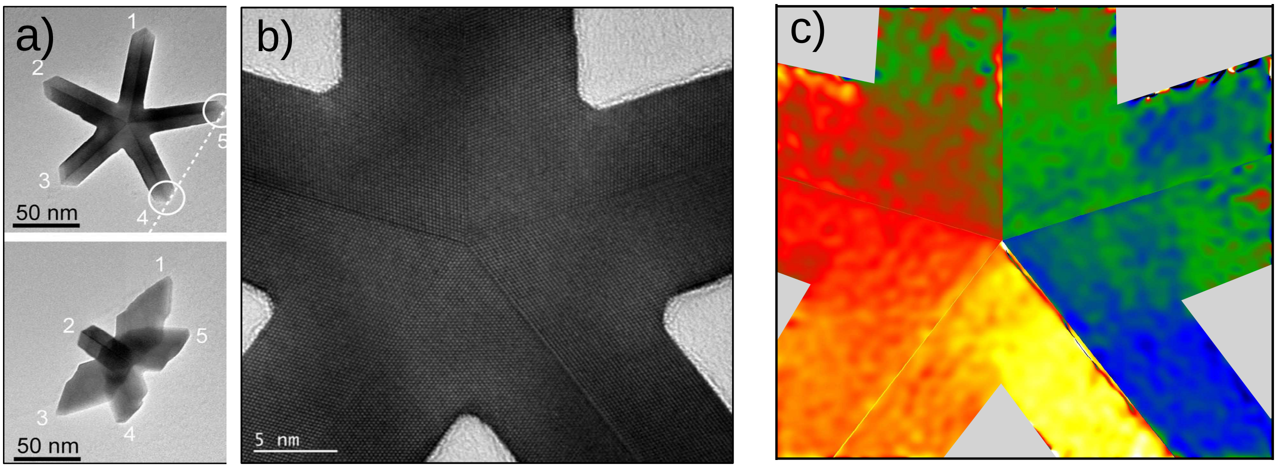
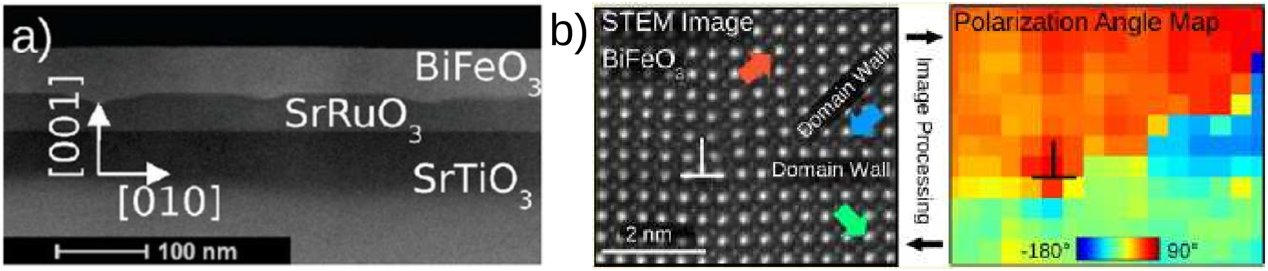
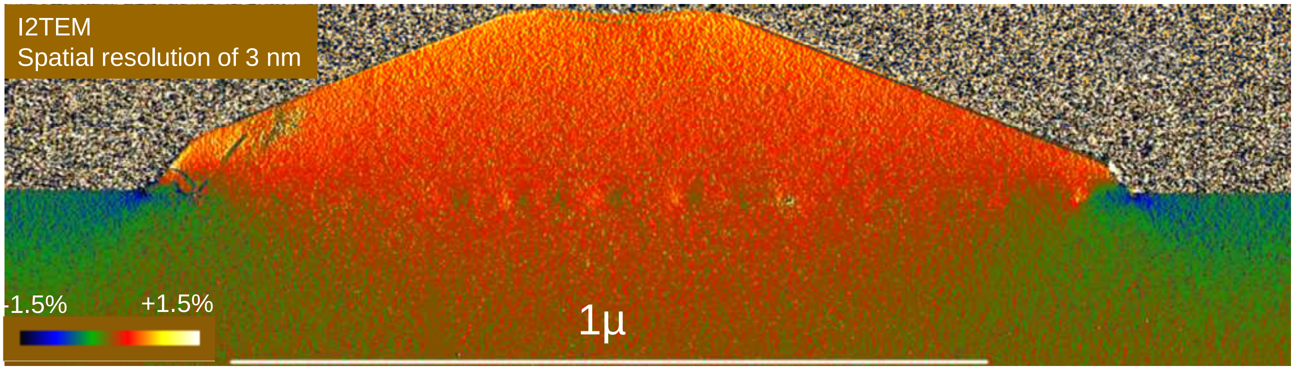


Figuře 1. Disclination in five-fold nanostars of Pt: (a) bright-field images of nanoparticle, in-plane and inclined; (b) aberration-corrected HRTEM image of nanoparticle core showing 5-fold twinning; (c) corresponding in-plane orientation map showing linearly increasing rotation around disclination core.



Figuře 2. Dislocations in $BiFeO_3$: (a) medium-resolution HAADF-STEM image of layer structure; (b) aberration-corrected atomic-resolution HAADF-STEM image of dislocation and domain boundary; (c) local polarization map determined from column displacements.



Figuře 3. Defects in strained-islands of SiGe on Si: horizontal deformation component mapped by DFEH on the I2TEM microscope with respect to silicon substrate.