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Crystallographic orientation maps obtained from ion and back scattered electron channeling contrast

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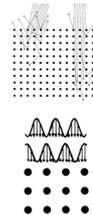
INTRODUCTION

For several years now, new directions have been explored to obtain orientation maps by other means than the classical Electron Back Scattered Diffraction (EBSD) setup, or to modify it aiming at improved information. Particularly, the channeling contrast may be used to obtain orientation maps, which is the approach presented here, called CHanneling ORientation Determination (CHORD) [1,2]. The main idea relies on the acquisition of an electron or ion image series when rotating a pre-inclined polycrystalline sample with respect to the beam. Along such image series, each (X,Y) pixel of the region of interest undergoes an intensity variation due to the channeling effect, that can be plotted as a function of the rotation angle. Such intensity profiles can be theoretically predicted for a given orientation of a crystal, as described in the following. The orientation is retrieved by a search in a database of theoretical profiles obtained by simulating intensity profiles for a large set of orientations. The principal issue is to model quantitatively for ions and electrons the channeling effect observed in such image series.

CHANNELING CONTRAST

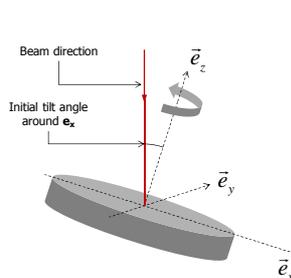
The channeling of the incident beam by crystallographic planes is responsible for the grey level difference between differently oriented grains in a polycrystalline material.

- if the ion beam is parallel to low index planes, the secondary electron are generated far under the surface. A low intensity is then detected.
- with an electron beam, the intensity received by the detector is monitored by back scattered diffraction including dynamical effects.



More details on the channeling effect available in ref [3]

ACQUISITION

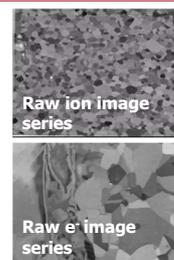


Starting point: beam perpendicular to the sample surface

- then tilting the sample → 40° for ions ; 10° for electrons
- then rotation of the sample around the tilted normal → one image acquisition every rotation step (automated)

Signal detection:

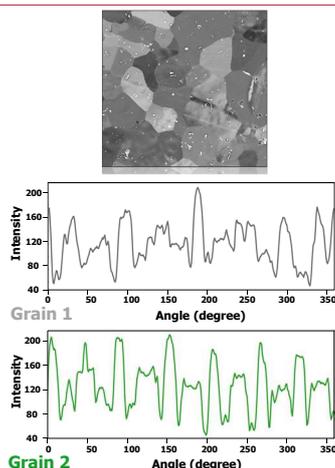
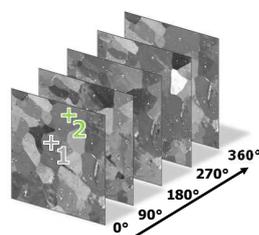
- e⁻ → back scattered electron detector
- Ga⁺ → ion-induced secondary electron detector



POST-TREATMENTS

From raw image series

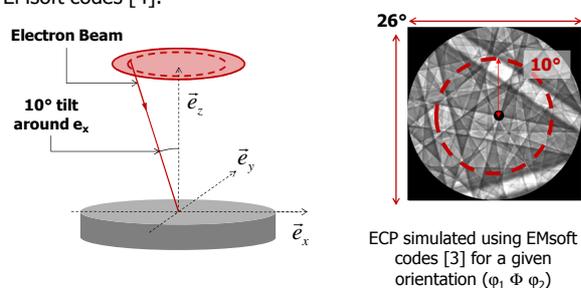
- Alignment
- Crop on the region of interest
- Denoising (eventually)



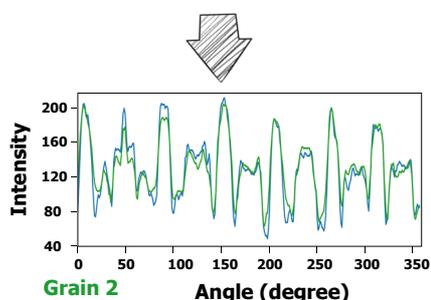
An experimental intensity profile is obtained for each (X,Y) position.

ELECTRON CHANNELING MODELIZATION

Based on similarities with Electron Channeling Pattern acquisition (ECP) ; diffraction including dynamical effects using M. De Graef EMOsoft codes [4].



Gathering the intensity along the ECP 10° circle...



STRATEGY TO RECOVER THE ORIENTATION

- construction of a database of theoretical intensity profiles

THEN

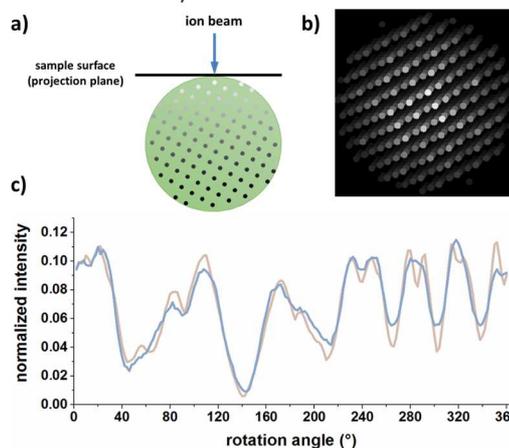
- pick up an intensity profile at (X,Y) position
- explore the database to find the closest theoretical one
- assign the corresponding theoretical orientation to the (X,Y) position



Generation of theoretical intensity profiles for ions and electrons

ION CHANNELING MODELIZATION

Ballistic description ; numerical approach based on the relationship between the « shadow » of the structure and the detected intensity



For Euler orientation ($\phi_1 \ \phi_2$) and each rotation angle, the intensity in the profile is the sum of grey levels in the projection.

REFERENCES

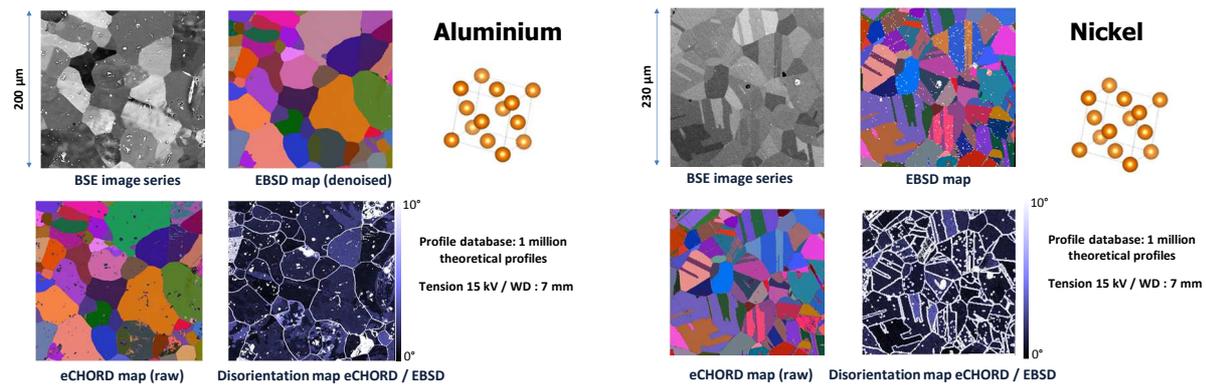
- [1] Langlois C. *et al.*, Ultramicroscopy 157 (2015), p. 65
- [2] Lafond C. *et al.*, Ultramicroscopy, 186 (2018), p. 146
- [3] Newbury D. E. *et al.*, Advanced Scanning Electron Microscopy and X-Ray Microanalysis, Springer (1986)
- [4] Singh S. & De Graef M., Microscopy and Microanalysis, 23 (2017), p. 1

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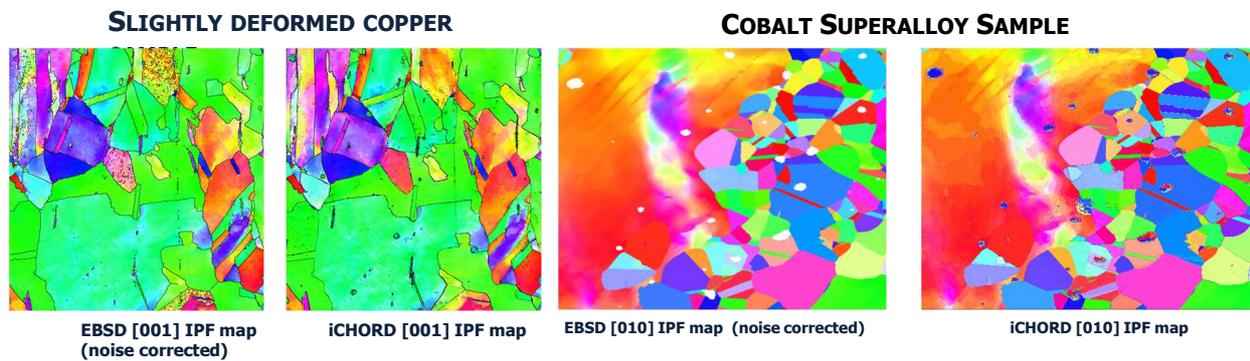
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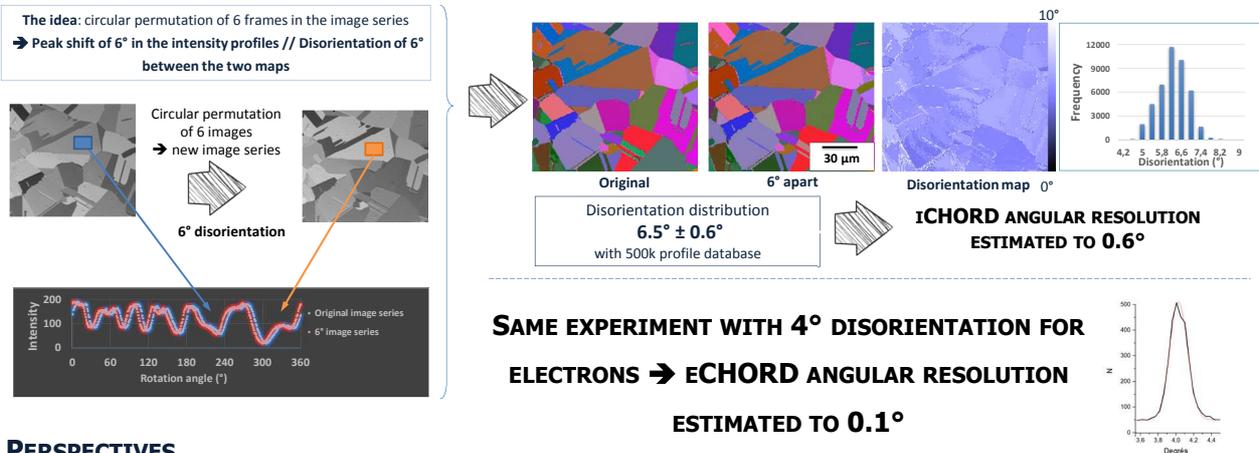
ECHORD: EXAMPLES



ICHORD: EXAMPLES

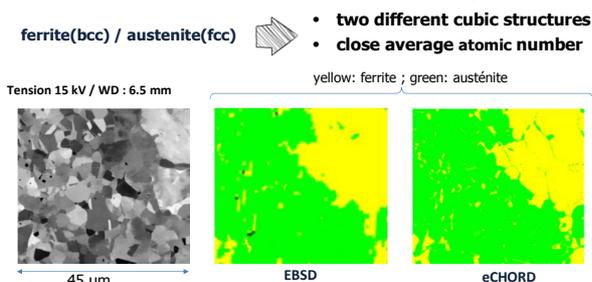


ANGULAR RESOLUTION OF ICHORD MAPS – EXAMPLE ON INCONEL SAMPLE

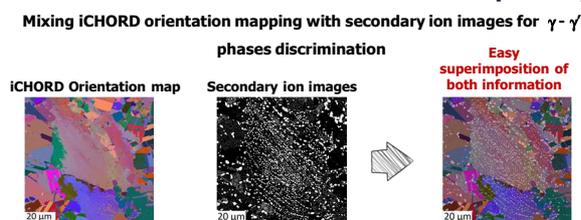


PERSPECTIVES

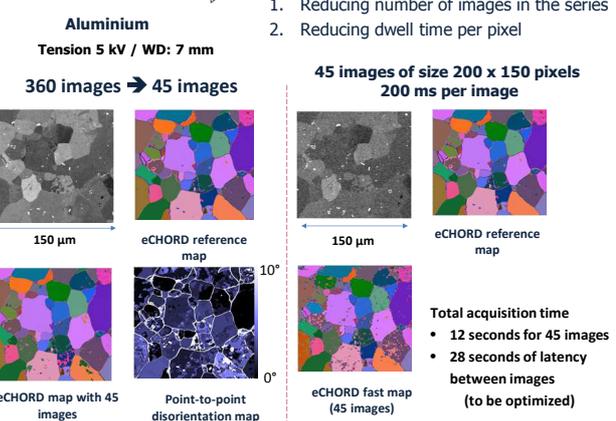
PHASE DISCRIMINATION – eCHORD on duplex steel



PHASE DISCRIMINATION – iCHORD on Ni superalloy



FAST CHORD



CONCLUSION

The CHORD approach for orientation mapping is an interesting compromise between angular //spatial resolution and acquisition speed.

- More on phase discrimination capability → oral presentation from C. Lafond on Monday 14:45, Meeting Room C4.1
- For a focus on acquisition and image treatments, → oral presentation from C. Langlois on Tuesday 16:00, Meeting Room C4.11