CHORD, an alternative method for orientation mapping: new features for phase discrimination

Clement, L.[1], Langlois, C.[1], Douillard, T.[1] and Cazottes, S.[1]

[1] MATEIS Laboratory, INSA , University of Lyon – CNRS, Lyon (France), France

CHanneling ORientation Determination (CHORD) [1,2] is an orientation mapping method that uses electron or ion channeling contrast to obtain crystalline orientation maps in a Scanning Electron Microscope (SEM) or Focused Ion Beam (FIB) microscope without using an extra detector or a dedicated camera. A sample is tilted with respect to the incident beam and rotated from 0° to 360°. At each rotation step, a back-scattered electron (BSE) image or an ion-induced secondary electron image of the region of interest (ROI) is acquired. After image processing, at each pixel of the ROI, an experimental intensity profile as a function of the rotation angle is obtained. These experimental profiles are then compared to a theoretical database of profiles to recover orientation. Many cubic monophasic polycrystalline materials were mapped using CHORD method, including copper, Ni-based and Al alloys, austenitic and ferritic steels. New CHORD developments include capabilities for phase discrimination. When the crystallographic phases are different enough, each experimental profile can be compared with both crystals databases. The best score database index is then assigned to the current position. If the crystallographic phases are close but differ by their atomic numbers (Z), one can combine experimental intensity profiles with chemical information present in BSE or secondary ion imaging. Both cases are illustrated in Figures 1 and 2.
Figure 1b presents an eCHORD phase map of an austeno/ferritic duplex steel ROI (Figure 1a). For this experiment, a 2 million theoretical profiles database has been used (1 million profiles for each phases). As a reference, an Electron Back Scattered Diffraction (EBSD) phase map of the same ROI is presented in Figure 1c, in a vivid agreement with the eCHORD phase map.

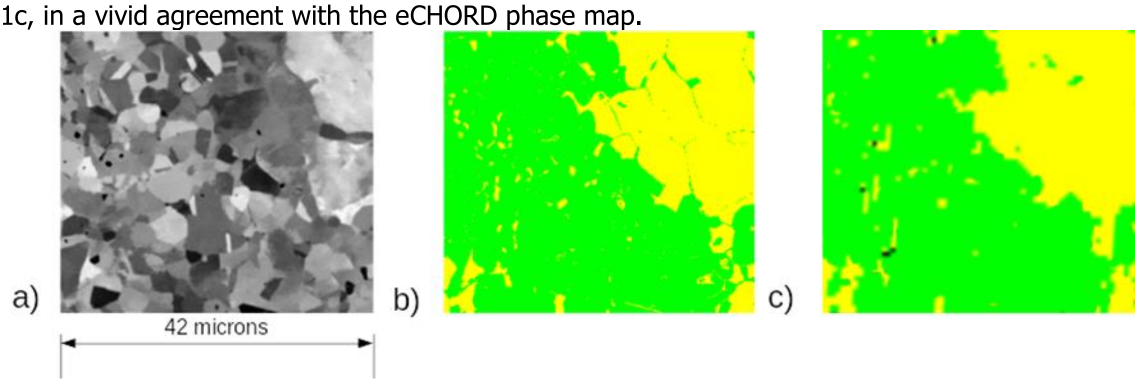

Figure 1: (a) BSE image of the region of interest of a duplex steel (b) eCHORD phase map of same area; austenite in green, ferrite in yellow (c) EBSD phase map using the same color code.

For iCHORD experiments, a secondary ion signal can be detected in parallel to the ion-induced secondary electron signal. In the case of γ/γ'superalloys (Figure 2), this secondary ion signal provides a strong contrast between the γ phase and the γ' phase. Both information can be easily superimposed thanks to the low sample tilt, allowing discriminating between the two phases with high spatial resolution and giving their crystallographic orientations.

These preliminary results demonstrate that phase discrimination using CHORD experiments is possible, with several strategies available depending on the characteristics of the sample.

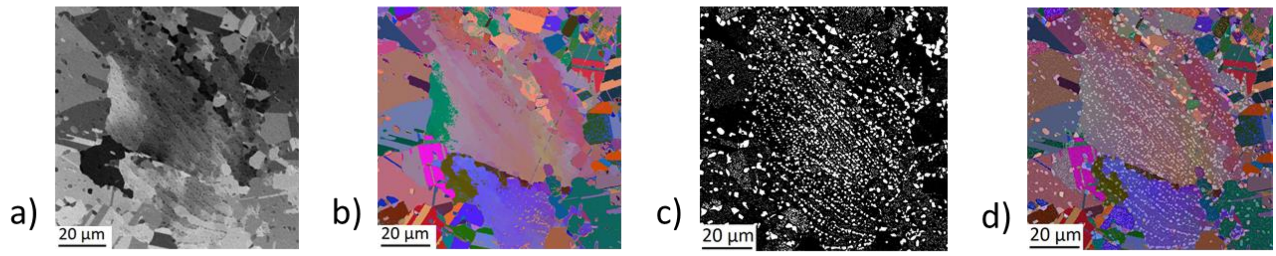

Figure 2: a) Nickel based superalloy with coexistence of γ and γ' phases. b) iCHORD orientation map. c) secondary ion chemical map image. d) Blending of chemical and orientation information with transparency.

[1] C. Langlois, T. Douillard, H. Yuan, N.P. Blanchard, A. Descamps-Mandine, B.V. de Moortèle, C. Rigotti, T. Epicier, Crystal orientation mapping via ion channeling: an alternative to EBSD, *Ultramicroscopy* 157 (2015) 65 - 72, doi: 10.1016/j.ultramic.2015.05.023.

[2] C. Lafond, T. Douillard, S. Cazottes, P. Steyer, C. Langlois, 2018, Electron CHanneling ORientation Determination (eCHORD): An original approach to crystalline orientation mapping, *Ultramicroscopy*, vol. 186, pp. 146-149, https://doi.org/10.1016/j.ultramic.2017.12.019.