

### Orientation and Phase Mapping with Transmission Electron Microscopes

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ACOM/TEM : Automated Crystal Orientation Mapping on TEM

- 'DigiStar' : Precession tool for TEM

= ASTAR



Nanocrystalline Al



TRIP steel with retained austenite







## 1) ACOM/TEM :

#### Template matching

#### Pattern acquisition and template generation



Combining orientation/phase identification with Electron Precession





## ACOM/TEM : Automated Crystal Orientation Mapping







### ACOM/TEM : Automated Crystal Orientation Mapping





Kikuchi pattern



Orientation  $\Omega$ 



Bragg Spot pattern



Orientation  $\Omega + \Omega' (= \Omega + 0.1^{\circ})$ 



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### ACOM/TEM : Orientation Indexing





## ACOM/TEM : Crystallographic orientation identification Cris



## ACOM/TEM : Reliability





## Deconvolution of superimposed Diffraction patterns



## ACOM/TEM : Phase identification and reliability



Austenite : Index  $I_2 = 389$ 



### ACOM/TEM : four steps





## **TEMdpa** : Diffraction Pattern Acquisition





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Save as

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## **TEMdpa : Virtual Bright Field on-line construction**





## **TEMdpa : Virtual Bright Field on-line construction**





Bright field image

Grenoble

Aluminium (mean grain size 200nm)



Orientation map

Virtual bright field image



### DiffGen : Template generator





Structure generator (lattice, cell, structure factor)



DiffGen : Template generator





## INDEX : pattern identification software







### ACOM : some examples of orientation maps



Deformed Cu (coll. N. Llorca – Univ. Barcelona, Spain)





Correlation Index

Orientation reliability



Phase Reliability



Orientations



Grenoble



Fe 1.67% C (HT 10 min @ 1100℃, A. Stormvinter - KTH)



Martensite

**Austenite** 



#### Grain size and Texture in 80 nm copper lines





500x100 steps (6.5 nm each) , Spot size 25 nm Scanning time : 19 min (44 fps)

Grenoble

Side view



300x100 steps (6.5 nm each), spot size 15 nm Scanning time : 12 min (44 fps)



SIDE VIEW (orientation and index superimposed map) The two scans were performed with different settings They demonstrated the reproducibility of the identification CROSS VIEW (orientation map)

Grain size of the order of 30 nm may be identify despite the use of a conventional LaB6 equipped Jeol 3010 TEM (spot size 25 nm). A fiber texture was detected within the channel.

250x100 steps (13 nm each) LaB6 equipped Jeol 3010 TEM (spot size 25 nm) Scanning time : 10 min (44 fps)





Credits: - Stefan BRANDSTETTER, SIMaP - Grenoble INP



### ACOM/TEM combined to a FEG-TEM



**JEOL 2010F** *Texas Material Institute UT, Austin* 

180 nm Cu lines

Pt nanocrystals



Virtual bright field

Orientation map

**Correlation Index map** 













## 1) ACOM/TEM :

Template matching

Pattern acquisition and template generation

## 2) ASTAR :

Combining orientation/phase identification with Electron Precession





# Precession Electron Diffraction patterns (R. Vincent, P.A. Midgley, Ultramicroscopy 53 (1994) 271.)





#### Precession Electron Diffraction patterns



Mayenite crystal ( $Ca_{12}AI_{14}O_{33}$ ) : space group I-43d



Without precession





## ACOM + Precession: Solving 180° orientation ambiguities



## ACOM + Precession: Solving 180° orientation ambiguities





### Practice ASTAR ('HRCOPM')



### 1) TEM practice (acquisition)

Grenoble INP

2) PC practice (indexing and viewing)

	Day 1 (Wednesday)		Day 2 (Thirsday)		Day 3 (Friday)	
	16 :00	17:30	16:30	18:00	13 :30	15:00
Groupe 1	<b>TEM</b> Room 0'503			<b>PC practice</b> Room 1'428		
Groupe 2	PC practice Room 1'428	<b>TEM</b> Room 0'503				
Groupe 3	PC practice Room 1'428		<b>TEM</b> Room 0'503			
Groupe 4		PC practice Room 1'428			<b>TEM</b> Room 0'503	
Groupe 5		<b>PC practice</b> Room 1'428				<b>TEM</b> Room 0'503



#### Indexing Fourier transform of High resolution TEM images







### DiffGen : Template generator







### ACOM : some examples of orientation maps





Orientation maps



## ACOM/TEM : Automated Crystal Orientation Mapping



Fe 1.67% C (HT 10 min @ 1100°C, A. Stormvinter - KTH)



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### Same area with (Y) and without (I) precession



TRIP steel (ferrite + austenite) ; Philips CM120 @ 100hz (6 min),









